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# Science Focus

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*Secrets of a*
ROLLERCOASTER DESIGNER

*Is cold water swimming*
A VACCINE AGAINST STRESS?

The feel-good issue

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OUR BEST FRIENDS' BIOLOGY COULD HOLD THE KEY TO AGEING WELL

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*ALSO IN THIS ISSUE*

**Immune System**
Can zinc supplements help keep COVID-19 at bay?

**The Genome**
Inside the largest ever database of human genetics

**Coronavirus**
How the pandemic will transform the modern office

THE AWARD-WINNING *SUNDAY TIMES* BESTSELLER

**'SO VERY IMPORTANT'**
**ADAM RUTHERFORD**

**'HELL YES'**
**CAITLIN MORAN**

# INVISIBLE WOMEN

## What happens when we ignore half of humanity?

CAROLINE CRIADO PEREZ

**'CHANGES THE WAY YOU SEE THE WORLD'**
***SUNDAY TIMES***

**'THIS IS A BRILLIANT EXPOSÉ'**
***GUARDIAN***

VINTAGE

# FROM THE EDITOR

After six months of reporting on the global pandemic, we felt it was time for something different: welcome to the feel-good issue. Put a brew on, put your feet up and enjoy some uplifting long-reads. Up first there's the hugely ambitious, mega project to test and analyse hundreds of thousands of pet dogs in the US to discover what makes some people age faster than others (p54). It might sound like an odd way to look at human ageing, but the fact that our four-legged companions share our lifestyles, our homes and sometimes even our diets means that the study will give us an unprecedented look at the changes we can all make to age well. And of course, it might just help a few good boys and girls enjoy a little more time with their humans too.

Over on p74, we're diving into the research of the benefits of cold water swimming. Thousands of swimmers up and down the country – and even some on our team – swear that there's nothing better for your mood or your health than a quick dip in some icy water, and now some scientists think they might be onto something. Alternatively, if you want to enjoy something out-of-this world, head to p33 where we've taken a look at the latest paper from NASA on the feasibility of warp drive.

And finally, if you haven't listened to our podcast before – what are you waiting for!? Head over to your favourite podcast app and search for *Science Focus*. This month, we've released a brilliant interview with behavioural scientist Dr Pragya Agarwal about racial bias, and an exclusive six-part mini-series with Prof Jim-Al-Khalili called Everything You Wanted To Know About… Physics.

Enjoy!

**Daniel Bennett,** Editor

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Would the dinosaurs have eaten us if we were alive at the same time? →p81

## CONTRIBUTORS

**DR HELEN PILCHER**
Science writer Helen reveals the processes that create some of the most colourful natural phenomena on Earth. →p46

**PROF MIKE TIPTON**
Could cold water swimming help stave off stress and depression? Mike is one of the scientists who's looking into its potential. →p74

**DR DANIEL MACARTHUR**
The gnomAD database is now live. It's a collection of the genetic variation in thousands of genomes. Daniel reveals what it might tell us about disease. →p24

**PROF BRENDAN WALKER**
Self proclaimed thrill seeker and engineer Brendan reveals the psychology and physiology of rollercoaster riders. →p70

## CONTACT US

**Advertising**
sam.jones@immediate.co.uk
0117 300 8145
**Letters for publication**
reply@sciencefocus.com
**Editorial enquiries**
editorialenquiries@sciencefocus.com
0117 300 8755
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**Other contacts**
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## ON THE BBC THIS MONTH...

**Ambulance**
The BAFTA winning documentary has returned to our screens, this time following the North West Ambulance Service.
**BBC One**
**Thursdays at 9pm, catch up on iPlayer**

**The Salisbury Poisonings**
In 2018, Sergei Skripal and his daughter Yulia were poisoned by a chemical nerve agent in Salisbury. This three part drama tells their story and the city's response to the subsequent public health crisis.
**Available on BBC iPlayer**

**CrowdScience: What's The Point Of Blood Groups?**
The team finds out why animals have different blood types and if cross species transfusions could ever save a human's life.
**BBC World Service**
**Available on BBC Sounds.**

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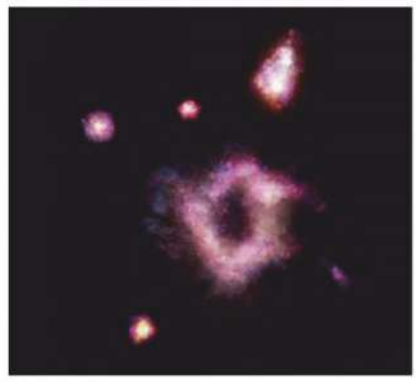
**13 DISCOVERIES**



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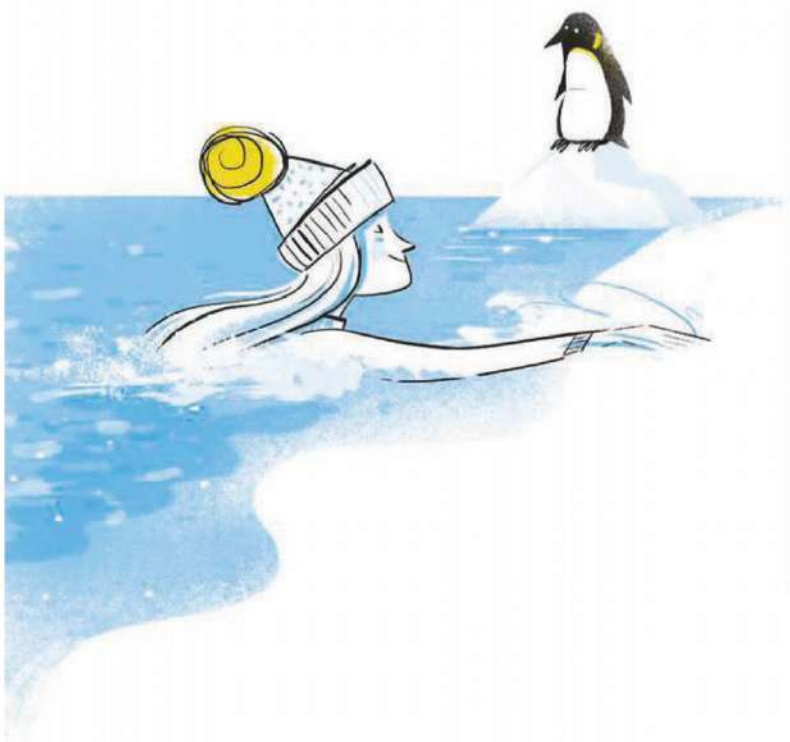

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## DOING IT FOR THE THRILL

“THRILL HAS EVOLVED AS A MECHANISM TO REWARD THE PERSISTENCE OF LIFE”

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Can’t wait until next month to get your fix of science and tech? Our website is packed with news, articles and Q&As to keep your brain satisfied.
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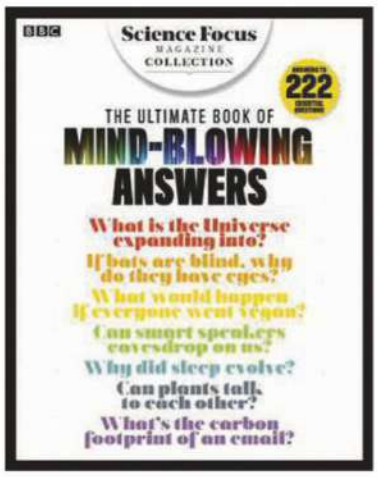
## SPECIAL ISSUE




**THE ULTIMATE BOOK OF MIND-BLOWING ANSWERS**

In this special edition, the experts from *BBC Science Focus* reveal the mind-blowing answers to the perplexing questions that baffle the brightest of brains.
**buysubscriptions.com/focuscollection**

EYE OPENER

# Splash light

**CALIFORNIA,** USA

In May, the waves crashing onto this Californian beach were transformed to bright blue, thanks to bioluminescent, microscopic plankton. Huge algal blooms like this occur every few years, when the conditions of the water and the nutrients available are just right.

It's thought that the organisms normally produce light in response to agitation in the water from a predator, explains David Caron, professor of biological sciences at the University of Southern California. "It would be the same if you were hunting in the dark and somebody put a bright flashlight in your eyes – it startles the predator, and in doing so, it gives a little bit of time to get away."

This light is the result of a chemical reaction. "The algae are mechanically stimulated to produce a molecule, called luciferin, and an enzyme, luciferase, that react with each other and create light," says Caron. "In fact, fireflies use a very similar process."

SHUTTERSTOCK

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# EYE OPENER

## Troubled waters

**OKAVANGO DELTA,**
BOTSWANA

These hippopotamuses, along with other African wildlife such as lions, elephants and giraffes, travelled across the Kalahari Desert last winter seeking a water source. As they do every year, the animals ended up at the Okavango Delta, a vast swamp-like basin that marks the end of the Okavango River.

While these hippos hoped to find food and drink, to socialise and submerge themselves in the water, they instead found drought-stricken land. What water was available had turned to pools of mud, explains photographer Talib Almarri, who took this photo from a helicopter.

Last year, southern Africa experienced one of its worst drought seasons, with both human and wildlife populations suffering. It is expected that as global temperatures rise, Botswana's dry seasons will become more severe, pushing more animals to their limits.

TALIB ALMARRI

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# CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

reply@sciencefocus.com

*BBC Science Focus*, Eagle House, Colston Avenue, Bristol, BS1 4ST

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LETTER OF THE MONTH

## The ethics of research

I have mixed feelings about the article on the effects of ocean plastic on turtles (April, p17). I've seen the damage that plastic is causing to our oceans myself – while diving in the Red Sea in Aqaba, Jordan I found a moray eel choked to death on the seabed with plastic tightly wrapped around its neck. But the article raised some questions. How ethical is it to take turtles captive to conduct research? Aren't we restricting the very freedom we're trying to give them, even in the name of science? What are we doing to help turtles we find with plastic in their system?
**Lynn Muldrew**

**Science offers the opportunity for us to try and prevent further damage to the marine environment. We need to understand why turtles eat plastic. The study gave us new information – that plastic not only looks like food, but smells like it too. Once researchers are armed with knowledge like this, they have solid evidence that can help us develop ways to prevent creatures from become affected by plastic, rather than acting on a hunch. Scientists always consider the ethics of their research, and after this study, the turtles were released.**

**Vets can X-ray rescued turtles to see if there is plastic in their bodies, and can attempt to remove it before rehabilitation and release. The effect of microplastics is less understood, and is an active area of research.**
**Alice Lipscombe-Southwell,** *managing editor,* BBC Science Focus

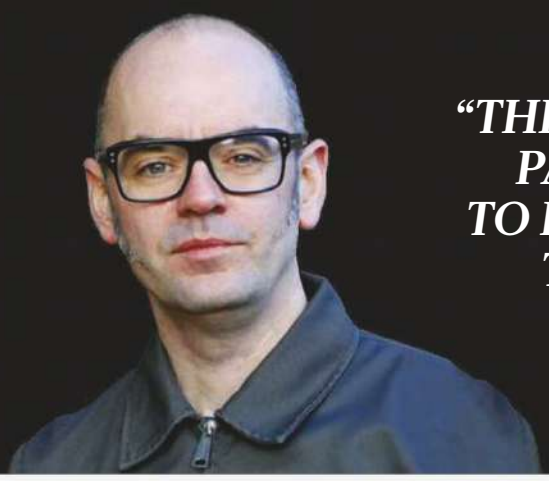
**WRITE IN AND WIN!**
The writer of next issue's *Letter Of The Month* wins a **Q800 Pro dashcam** from Thinkware. It has a QHD wide-angle forward-facing camera, HD rear-facing camera and night vision. It also comes with cloud connectivity, where you can locate the vehicle, and alert others in case of impact.
**thinkwaredashcam.store**

## A pointless vaccine?

In 'The race to create a vaccine' article (May, p52) you say it can take "10 years or more" to get a vaccine ready. Does that mean that the flu jab I get every year won't protect me from any new strain that has arisen in the last 10 years? Doesn't that make the flu vaccination almost useless?
**Henry Parr,** *Frome*

**It can take 10 years or more to develop an entirely new vaccine, but the annual flu vaccine is developed in a matter of months. Each year's vaccine protects against the flu viruses that are making most people ill at that time. The vaccine is quick to develop because there are similarities between the different flu viruses each year, and the manufacturing process is well-tested. Developing a vaccine for a new virus such as SARS-CoV-2, on the other hand, requires extra time to make sure that the vaccine is safe, effective and capable of being scaled up to hundreds of millions of doses.**
**Andy Ridgway,** *science writer*

There's no need for complicated drinking tricks to cure hiccups, says Kathy Turner



*"THE ACTUAL DANGER OF THE THEME PARK, WELL, YOU'RE MORE LIKELY TO FALL OFF A DONKEY IN SKEGNESS THAN HAVE ANY ACCIDENTS ON A THEME PARK RIDE"*

BRENDAN WALKER, p70

How to spot a fake person? They're too perfect!

GETTY IMAGES X2, THISPERSONDOESNOTEXIST.COM

## Can't fool me

The first of the '20 ideas you need to know about in 2020' (March, p77) was about technology being able to fake faces convincingly. However, when I took a look at the website referred to in the article, I was not convinced.

The faces were all too perfect. There was not a spot, pimple or scar in evidence on any of the faces and hardly a freckle or wrinkle. They all had symmetrical faces, and, in fact, I think they all had the same teeth!

**Jenny Newton,** *Dorchester*

## Deep breath in...

Reading the old wives' tale on curing hiccups (March, p94), I remembered that when I was at school (way back in the dark ages!) my biology teachers told us that hiccups was caused by vibrations of the diaphragm which were out of sync. I've always managed to control hiccups by breathing deeply and slowly – it always works within a few minutes.

**Kathy Turner**

## Up is the wrong direction

Having read an excellent article by Dr Stuart Clark about the Voyager spacecraft (March, p26), I found it enjoyable but of little use to our lives. I feel your articles are heading off in the misguided direction that scientific exploration into space will be of a major benefit to people living on Earth.

As exciting as it seems, sending missions to Mars or exploring black holes will all be of very little benefit to our populations. How will this help with dwindling food supplies? Plastic in our oceans, corals dying, sea levels rising?

I cannot accept the argument that innovation for space exploration is what drives invention. Let us instead look after our dying planet.

**Peter Harris,** *Bristol*

## Oops!

In the May issue, we wrote that the Olympic National Park has 73,000 miles of coastline – this should have been 73 miles.


## THE TEAM

**EDITORIAL**
**Editor** Daniel Bennett
**Managing editor** Alice Lipscombe Southwell
**Commissioning editor** Jason Goodyer
**Staff writer** James Lloyd
**Editorial assistant** Amy Barrett
**Production assistant** Holly Spanner
**Online editor** Alexander McNamara
**Online assistant** Sara Rigby
**Science consultant** Robert Matthews

**ART**
**Art editor** Joe Eden
**Deputy art editor** Steve Boswell
**Designer** Jenny Price
**Picture editor** James Cutmore

**CONTRIBUTORS**
Acute Graphics, Scott Balmer, Abigail Beall, Peter Bentley, Dan Bright, Steve Brusatte, Emma Davies, Cathal Duane, Pete Etchells, Stuart Farrimond, Alexandra Franklin Cheung, Adam Gale, Helen Glenny, Alice Gregory, Alastair Gunn, Adam Hylands, Christian Jarrett, Aleks Krotoski, Michael Mosley, Stephanie Organ, Helen Pilcher, Jason Raish, Andy Ridgway, Jeremy Rossman, Helen Scales, Jocelyn Timperley, Luis Villazon, Joe Waldron.

**ADVERTISING & MARKETING**
**Group advertising manager** Tom Drew
**Advertisement manager** Sam Jones 0117 300 8145
sam.jones@immediate.co.uk
**Business development manager** Dan Long
daniel.long@immediate.co.uk
**Brand sales executive** Hannah Rich
hannah.rich@immediate.co.uk
**Newstrade manager** Helen Seymour
**Subscriptions director** Jacky Perales Morris
**Direct marketing manager** Kellie Lane

**MOBILE**
**Head of apps and digital edition marketing**
Mark Summerton

**INSERTS**
Laurence Robertson 00353 876 902208

**LICENSING & SYNDICATION**
**Director of licensing and syndication** Tim Hudson
**International partners manager** Anna Brown

**PRODUCTION**
**Production director** Sarah Powell
**Production coordinator** Derrick Andrews
**Ad services manager** Paul Thornton
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**PUBLISHING**
**Commercial director** Jemima Dixon
**Content director** Dave Musgrove
**Group managing director** Andy Marshall
**CEO** Tom Bureau

**BBC STUDIOS, UK PUBLISHING**
**Chair, editorial review boards** Nicholas Brett
**Managing director, consumer products and licensing**
Stephen Davies
**Head of publishing** Mandy Thwaites
**Compliance manager** Cameron McEwan
**UK publishing coordinator** Eva Abramik
Contact UK.Publishing@bbc.com
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**EDITORIAL COMPLAINTS**
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# Science Focus

MAGAZINE

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Martian formations made by mud, not lava p17

### END OF MALARIA?
Microbe could stop malaria in its tracks p18

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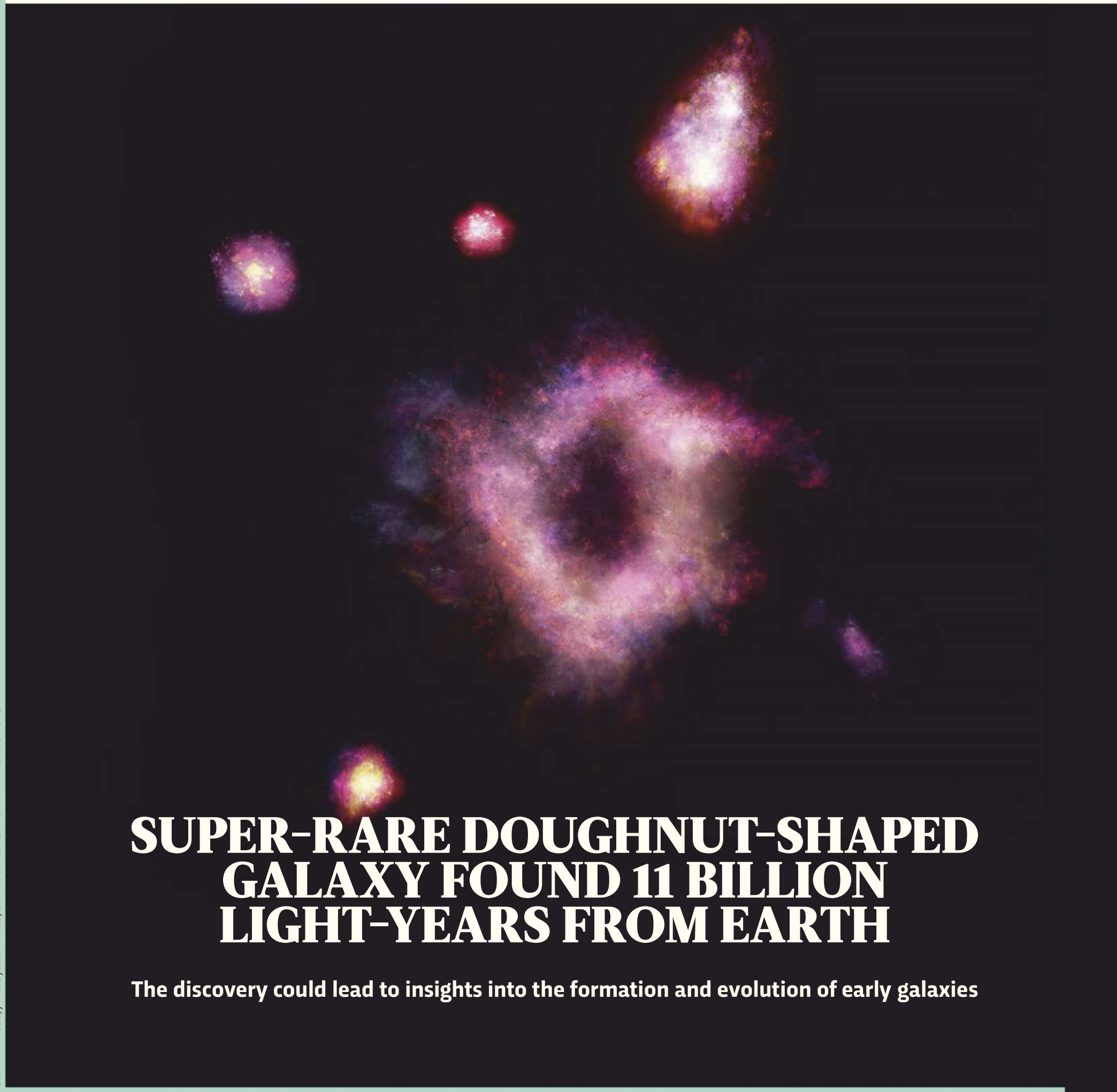

## SUPER-RARE DOUGHNUT-SHAPED GALAXY FOUND 11 BILLION LIGHT-YEARS FROM EARTH

**The discovery could lead to insights into the formation and evolution of early galaxies**

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**Heart neurons mapped** Cardiac nervous system showcased on cellular scale p20 **Ocean pollution** 'Hidden' pollutants like pesticides and heavy metals are just as harmful as plastics p22 **SpaceX** Crew Dragon shuttle successfully docks with ISS p26

# News in brief

## ANCIENT ANTARCTIC ICE RETREATED 50M A DAY

Global warming that ended the last Ice Age caused the Antarctic ice shelf to retreat up to 50 metres per day – 10 times faster than the rate observed today, a study at the University of Cambridge has found.

In the last period of rapid deglaciation, some 12,000 years ago, the ice along the Antarctic continental shelf broke up into sheets. This stirred up sediment on the seafloor leaving patterns of delicate, 'wave-like' ridges that can be used to calculate the rate of the ice's recession.

If climate change continues to weaken ice shelves, we could see similar rates of retreat, raising sea levels all over the world, the researchers warn.

Data from Hawaii's WM Keck Observatory helped researchers find the doughnut galaxy

Astronomers have captured an image of a galaxy shaped like a 'cosmic ring of fire', using data gathered by the WM Keck Observatory in Hawaii and images recorded by NASA's Hubble Space Telescope.

The circular galaxy, dubbed R5519, is located 11 billion light-years away from us, and is roughly the same mass as the Milky Way. It has a hole in its centre that is two billion times longer than the distance between the Sun and the Earth, and is a hotbed of star-making activity.

"It is a very curious object that we've never seen before. It looks strange and familiar at the same time," said lead researcher Dr Tiantian Yuan, from Australia's ARC Centre of Excellence for All Sky Astrophysics in 3 Dimensions (ASTRO 3D). "It is making stars at a rate 50 times greater than the Milky Way. Most of that activity is taking place on its ring – so it truly is a ring of fire."

Since it is 11 billion light-years away, the researchers are currently observing what was occurring in R5519 11 billion years ago, as it has taken that long for the light to travel from the galaxy to Earth. This means that they are seeing R5519 just three billion years after the Big Bang, making it an ideal candidate for the study of galaxy formation and evolution.

**"It is making stars at a rate 50 times greater than the Milky Way. Most of that activity is taking place on its ring. It truly is a ring of fire"**

The data suggests that R5519 is a collisional ring galaxy – a galaxy that formed as a result of immense and violent encounters with other galaxies, rather than the more common type of ring galaxy that forms due to internal processes. If so, it would be the first collisional ring galaxy ever located in the early Universe.

According to the researchers, these findings could have implications for helping scientists to understand how galaxies form. "The collisional formation of ring galaxies requires a thin disk [defining features of spiral galaxies] to be present in the 'victim' galaxy before the collision occurs," said co-author Prof Kenneth Freeman from the Australian National University. "In the case of this ring galaxy, we are looking back into the early Universe by 11 billion years, into a time when thin disks were only just assembling. For comparison, the thin disk of our Milky Way began to come together only about nine billion years ago. This discovery is an indication that disk assembly in spiral galaxies occurred over a more extended period than previously thought."

**ART LOVERS**
Researchers at The European Synchrotron Radiation Facility have figured out why Edvard Munch's 1910 version of *The Scream* has begun to degrade: he used impure cadmium yellow paint, which degrades even in relatively low humidity. Now, curators at the Munch Museum in Oslo, where the painting is kept, can work on measures to save it.

**NAP TAKERS**
Replacing prolonged periods of sitting around with a nice nap can help lower stress, body mass index (BMI), and improve mood, a study at Iowa State University has found.

## Good month

## Bad month

**FAST FOOD LOVERS**
Look away burger fans! A study at the Ohio State University has found that eating meals high in saturated fats could hinder our ability to concentrate. The effect could be down to saturated fats causing inflammation in our bodies, and possibly our brains.

**MANUAL WORKERS**
Physically demanding jobs may lead to shorter working lives, more sick days, and more unemployment, a study of more than 1.6 million Danish workers has found.

GETTY IMAGES X2, JULIUS CSOTONYI ILLUSTRATIONS: CATHAL DUANE

The dinosaur *Borealopelta markmitchelli* appeared to be a fan of ferns

PALAEONTOLOGY

# Revealed: the last supper of an armoured dinosaur

You might find this one hard to stomach. Scientists have analysed the fossilised guts of a 110-million-year-old dinosaur, revealing the beast's final meal.

The football-sized stomach forms part of an incredibly well-preserved fossil of a stocky, heavily armoured dinosaur known as a nodosaur, which was discovered in a Canadian mine in 2011.

After eating its final meal, the dinosaur, *Borealopelta markmitchelli*, died and got washed out to sea – perhaps during a flood. It sank to the seabed and was quickly entombed by mud, where it remained for millions of years. By the time it was uncovered, its seafloor burial site had become part of a mine in Alberta.

"The finding of the actual preserved stomach contents from a dinosaur is extraordinarily rare," said team member Dr Jim Basinger at the University of Saskatchewan, Canada. "This stomach recovered from the mummified nodosaur … is by far the best-preserved dinosaur stomach ever found to date."

It appears that this dinosaur had a particular fondness for ferns.

"When we examined thin sections of the stomach contents under a microscope, we were shocked to see beautifully preserved and concentrated plant material," said team co-leader Dr David Greenwood at Canada's Brandon University. "The last meal of our dinosaur was mostly fern leaves – 88 per cent chewed leaf material and 7 per cent stems and twigs."

This is the first definitive evidence of the diet of a large, plant-eating dinosaur. This animal seems to have been a fussy eater, choosing to eat particular ferns over others, and turning up its nose at the leaves of cycads and conifers, which would have been common in its Early Cretaceous habitat.

Its stomach also contains charcoal from burnt plant fragments, indicating that the animal was grazing in a burnt landscape, perhaps taking advantage of the first flush of ferns following a wildfire.

Now, researchers will continue to analyse the fossil of *B. markmitchelli*, which promises to offer many more insights into the dinosaur's environment and behaviour.

### YOGA MAY HELP EASE THE SYMPTOMS OF MIGRAINE

Regular yoga sessions could reduce the frequency of painful headaches in migraine sufferers, a study carried out at the All India Institute of Medical Sciences in New Delhi has found. The study involved 114 people aged 18 to 50 who suffered from episodic migraines, experiencing between 4 and 14 headaches per month. The team split them into two groups: one that took medication, and one that took medication but also practised a one-hour yoga routine five times a week. After three months, the yoga group reported a 48 per cent reduction in headaches, compared to a 12 per cent reduction for the medication-only group.

## In numbers

**3**

**The distance, in kilometres, that noises made by European spiny lobsters travel underwater. They make the sounds by rubbing their antennae on a raspy area beneath their eyes.**

**12,000**

**The journey, in kilometres, travelled by a cuckoo called Onon. It's one of the longest migrations by a land bird ever to be recorded. Onon set off from Zambia on 20 March this year, and arrived in Mongolia on 27 May.**

**14**

**The amount, in millimetres, that melting ice sheets in Antarctica and Greenland have raised global sea levels since 2003, as calculated by researchers at the University of Washington.**

ENTOMOLOGY

# 'Virgin birth' gene identified in Cape bees

The Cape bee is a subspecies of honeybee that's native only to the southern tip of South Africa. What makes it different from other honeybees is that the female worker bees are able to lay eggs that develop into other female bees. These eggs are not fertilised (worker bees are unable to mate), so this is a form of asexual reproduction, known as 'thelytoky'. The Cape bees are essentially creating a clone.

In Cape bees, this cloning trick only develops once the colony's queen bee dies. By producing female bees, they can give birth to the colony's new queen, ensuring that the colony survives.

In other honeybee subspecies, if the queen is lost the worker bees will occasionally lay unfertilised eggs, but these only develop into males, leading to the eventual collapse of the colony.

The Cape bee's ability comes at a cost, though. "Instead of being a cooperative society, Cape honeybee colonies are riven with conflict because any worker can be genetically reincarnated as the next queen," said study leader Prof Benjamin Oldroyd at the University of Sydney, Australia. "When a colony loses its queen, the workers fight and compete to be the mother of the next queen."

By comparing the genetic sequences ('genomes') of Cape bees to those of other honeybee subspecies, Oldroyd and colleagues were able to identify the gene that causes these births, called 'GB45239'. "It is extremely exciting," said Oldroyd. "Scientists have been looking for this gene for the last 30 years. Now that we know it's on chromosome 11, we have solved a mystery."

According to Oldroyd, continued research into the Cape honeybees could help us understand two major evolutionary transitions: the origin of sex and the origin of animal societies.

Furthermore, the scientists think that if they could decipher exactly how the gene works, it could raise the possibility of controlling a switch that allows animals to reproduce asexually, which could have important implications for agriculture and other fields.

**Cape honeybee workers can also parasitise the hives of other honeybee subspecies**

GETTY IMAGES, SHUTTERSTOCK, PETR BROZ/CZECH ACADEMY OF SCIENCES, ESA/MARS EXPRESS

On Earth, mud flows away from a mud volcano in Azerbaijan, and tracks on Mars (inset) may have formed in a similar way

MARS

# Mysterious Martian formations made by mud, not lava

**Scientists recreated Martian conditions on Earth to find out what caused these oozing trails**

Huge Martian landforms that look like ancient lava flows were actually caused by mud, scientists have discovered.

There are tens of thousands of these formations on the Red Planet's surface, reaching hundreds of kilometres in length. They occur where ancient liquids have flowed downhill, scouring out massive channels.

They look similar to lava flows on Hawaii, but their true nature has evaded scientists – until now.

A team of European researchers used the 'Mars Chamber' at the Open University in the UK, to simulate the movement of mud on Mars and Earth.

Inside this vacuum chamber, it's possible to recreate the low atmospheric pressures and cold temperatures of -20°C found on the Martian surface. In Earth-like conditions, the mud flowed freely, but in Martian conditions, the mud formed unusual shapes similar to those seen in spacecraft images of the Red Planet.

This happened because the Mars-like mud rapidly gained a frozen crust. Liquid mud spilled out through ruptures in the crust, and then refroze to form new shapes.

The mud on Mars is thought to have come from catastrophic flooding, comparable to the largest floods ever to have occurred on Earth. As the floodwater seeped beneath the surface, it took sediments with it, which could erupt to the surface again as mud.

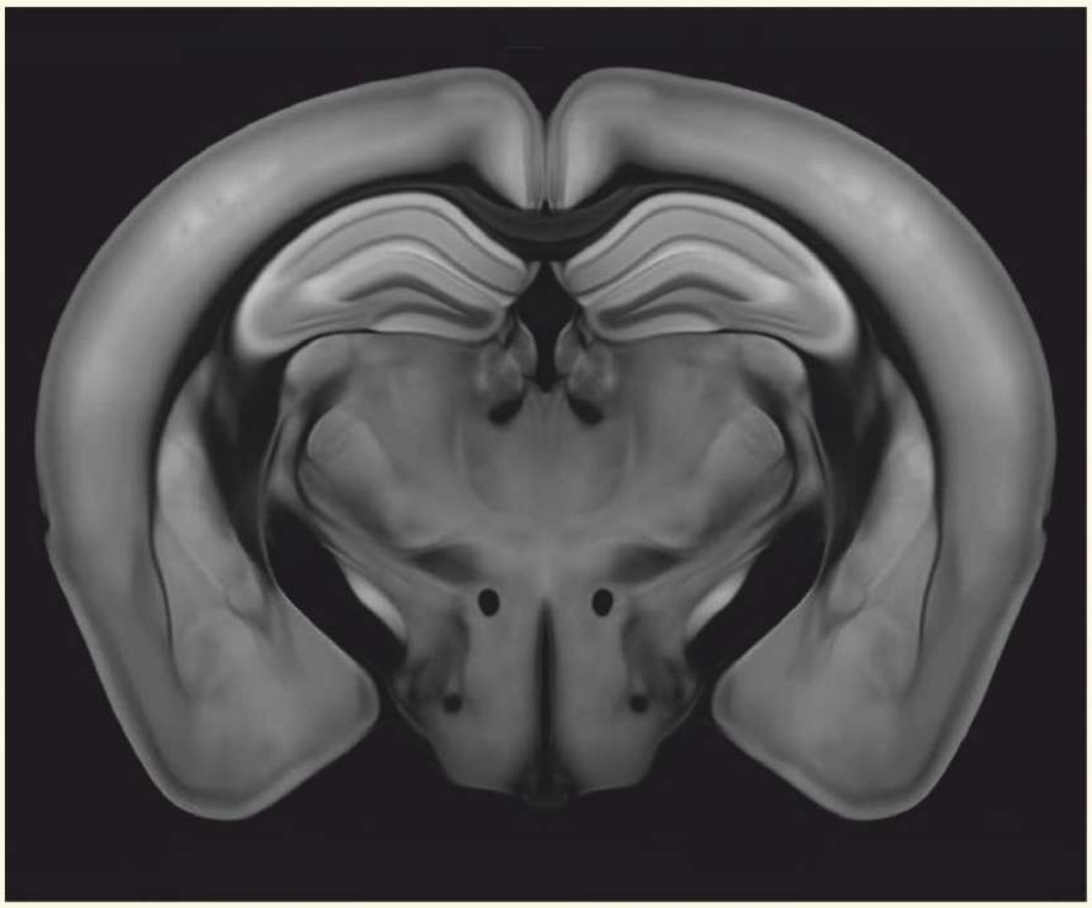
> **"Similar processes may apply to eruptions of mud on icy bodies in the outer Solar System, like on Ceres"**

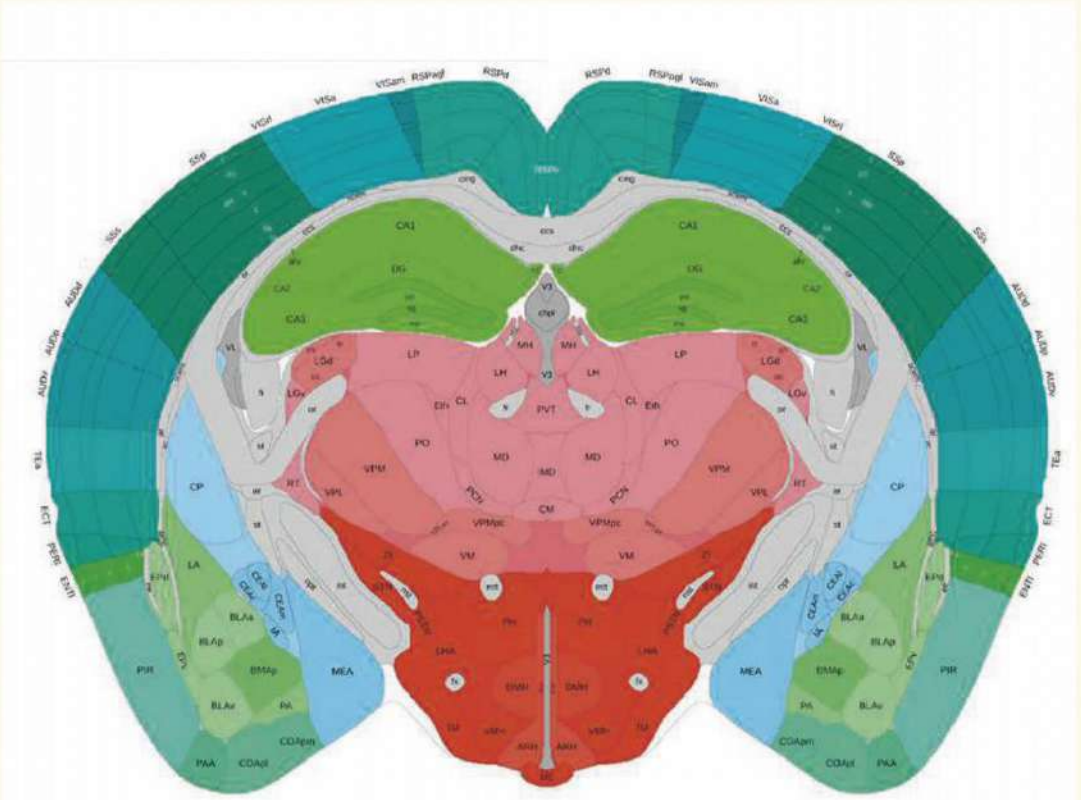
This process, called 'sedimentary volcanism' may also occur on the dwarf planet Ceres, which could harbour a muddy water ocean beneath its icy crust.

"We suggest that mud volcanism can explain the formation of some lava-like flow morphologies on Mars, and that similar processes may apply to eruptions of mud on icy bodies in the outer Solar System, like on Ceres," said Dr Petr Brož, lead author of the study at the Czech Academy of Sciences.

### MEET THE MICROBE THAT IS MAKING MOSQUITOES MALARIA-FREE

Each year, there are around 400,000 deaths from malaria, which is caused by a species of mosquito parasite called *Plasmodium*. The mosquito, though not affected by the parasites, carries them in its saliva, which it injects into its victim before blood is drawn. Now, scientists at the International Centre of Insect Physiology and Ecology in Kenya and the University of Glasgow have discovered a single-celled microbe that prevents mosquitoes from being able to carry and transmit *Plasmodium*. The microbe, named *Microsporidia MB,* was found to be naturally occurring in mosquito populations in Kenya. *Microsporidia MB* enters the ovaries of female mosquitoes and is passed onto her offspring without causing harm, which will hopefully allow it to rapidly spread through the mosquito population.





A virtual section of the 3D reference atlas of the mouse brain (top), and an accompanying graphic showing the different brain regions (above)

NEUROSCIENCE

# Mouse brain mapped with single-cell resolution

A new 3D reference atlas of the mouse brain will enable researchers to zoom down to the level of a single cell. By studying the mouse brain's structure in such detail, neuroscientists will be able to advance their understanding of how the mouse brain functions, and how this functioning can go wrong.

The atlas – called the 'Allen Mouse Brain Common Coordinate Framework', or 'CCFv3' – was created by researchers at the Allen Institute for Brain Science in Seattle. They averaged the brain scans of 1,675 mice, made using a technique called 'serial two-photon tomography'. This works by shining a laser on the brain tissue and measuring how the tissue 'fluoresces' (emits light), in response.

Each point on the atlas's 3D grid was labelled according to the brain structure to which it belongs. In total, the researchers labelled more than 800 structures, including several that hadn't featured in previous mouse brain atlases.

Brain atlases are useful for neuroscientists because they provide a reference when studying brain disease. For instance, this atlas will allow researchers to compare the volumes of different brain structures in healthy and diseased mouse brains. This could in turn lead to insights into the human brain, as mice are often used as a model for understanding human neurological disease – partly because our genomes are so similar (around 90 per cent of genes associated with disease in mice have counterparts in humans).

"We hope the wider neuroscience community will use it as a new standard reference atlas," said co-senior author of the study Dr Lydia Ng. "By making our atlas and related tools open access, new data and data types generated across our community can be more easily integrated and compared in the same spatial context, and the atlas in turn can be modified as our knowledge about brain structure evolves."

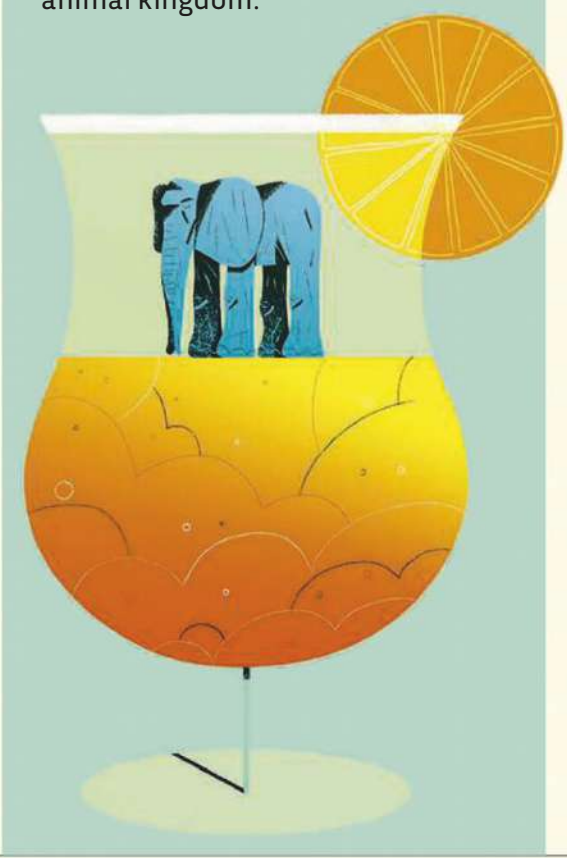
## They did what?

# Elephants' alcohol tolerance analysed

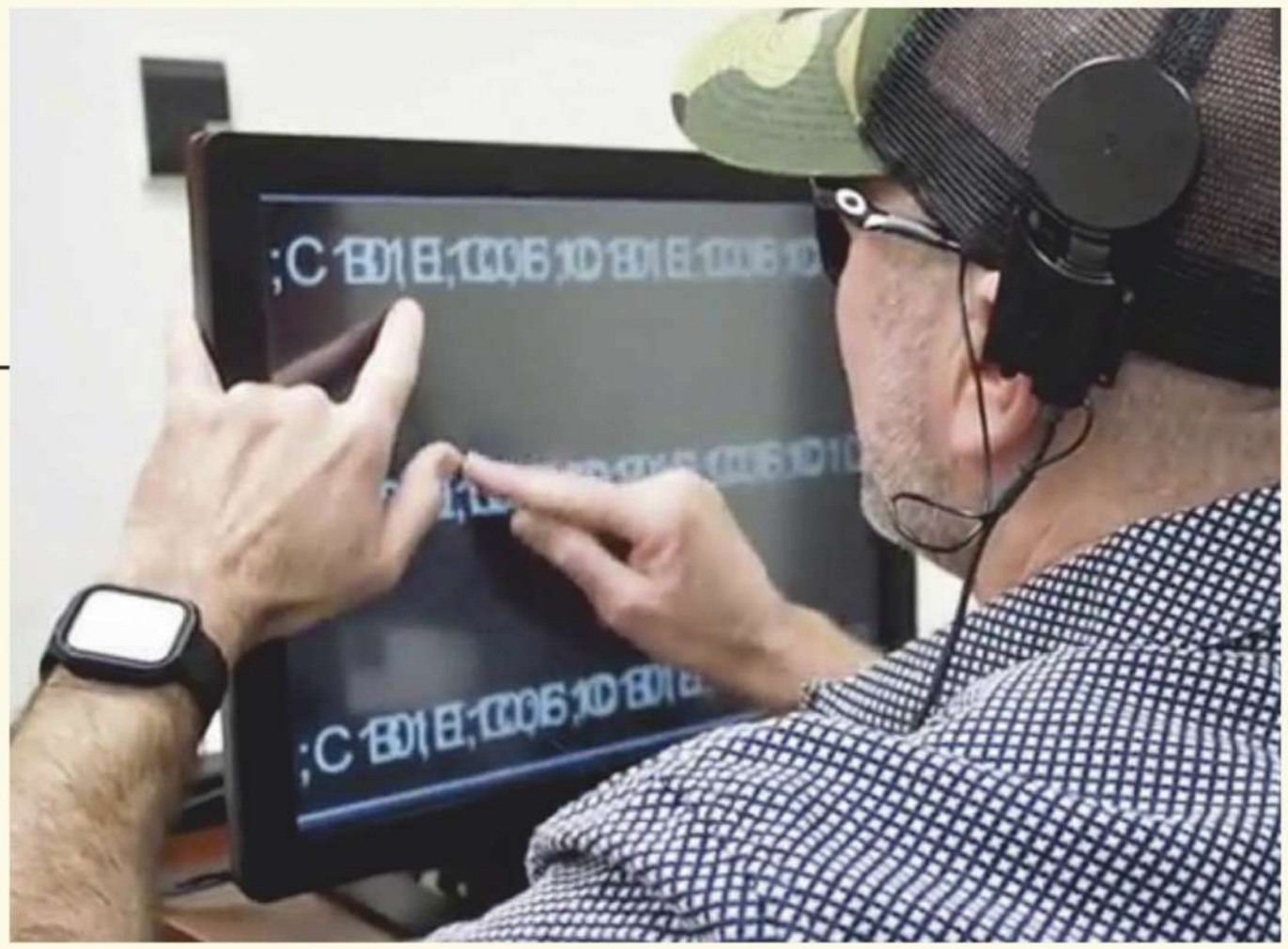
**WHAT DID THEY DO?**
Researchers at the University of Calgary compared the variations in a gene called ADH7 in 85 different species of mammals. ADH7 codes for an enzyme that is known to enable humans to break down alcohol up to 40 times faster than any other primate.

**WHY DID THEY DO THAT?**
Across the globe there is a substantial amount of anecdotal evidence of animals becoming drunk after consuming fruit that has started to ferment and produce alcohol. The team were particularly interested in stories of African elephants becoming intoxicated after chowing down on the overripe fruit of the marula tree.

**WHAT DID THEY FIND?**
It was previously thought it was unlikely for elephants to get tipsy thanks to their sheer size. However, the team found that elephants are poor metabolisers of alcohol and may be the lightweights of the animal kingdom.



ALLEN INSTITUTE FOR BRAIN SCIENCE, GETTY IMAGES, BEAUCHAMP ET AL ILLUSTRATIONS: CATHAL DUANE



Patients 'saw' letters in their brains via electrical stimulation, then drew those letters onto a screen

MEDICINE

# Electrical implants partially restore sight in blind patients

For most adults who lose their vision, it is as a result of damage to the eyes or optic nerve. For years, scientists have attempted to create a device that could restore sight by bypassing damaged eyes or nerves and sending images directly to the brain. Now, a team of researchers at Baylor College of Medicine in Houston, Texas, have come one step closer to this goal by using implanted electrodes to trace shapes directly onto the surface of blind patients' visual cortices, which is the part of the brain that deals with sight.

The team tested the idea on four sighted people who had electrodes implanted in their brains to monitor epilepsy, and two blind people who had electrodes implanted over their visual cortices as part of a different study.

"When we used electrical stimulation to dynamically trace letters directly on patients' brains, they were able to 'see' the intended letter shapes and could correctly identify different letters," said senior researcher Dr Daniel Yoshor. "They described seeing glowing spots or lines forming the letters, like skywriting."

However, the technology is still in its infancy and there are several significant obstacles that must be overcome.

"The primary visual cortex, where the electrodes were implanted, contains half a billion neurons. In this study we stimulated only a small fraction of these neurons with a handful of electrodes," said lead researcher Prof Michael Beauchamp. "An important next step will be to work with neuroengineers to develop electrode arrays with thousands of electrodes, allowing us to stimulate more precisely. Together with new hardware, improved stimulation algorithms will help realise the dream of delivering useful visual information to blind people."

### NOVEL EXPERIENCES LEAD TO GREATER HAPPINESS

People with more variety in their daily routine feel happier and more relaxed, a study at New York University has found. By tracking people's movements in New York and Miami, pre-COVID-19 restrictions, the team found that those who visited more locations during the day reported more positive feelings. MRI scans of some of the participants also showed greater brain activity between the region of the brain responsible for processing new information (the hippocampus) and the region that is associated with reward (the striatum). At a time when diversity in daily life is limited, the researchers have noted that even small changes to physical or mental routine, such as walking a different route or trying new exercises, could have the same impact.

BIOLOGY

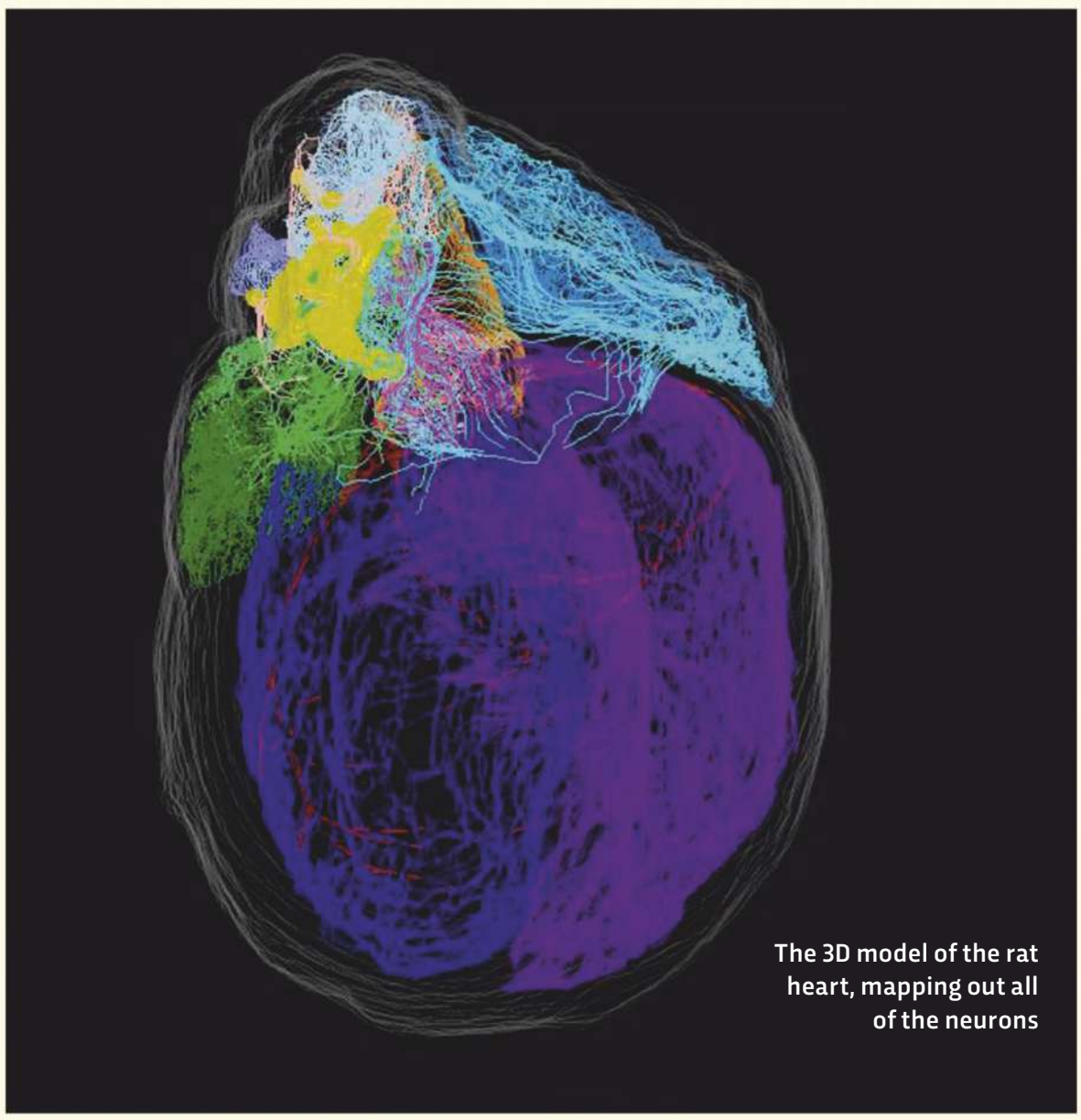
# Heart's nervous system mapped for first time

Most people tend to associate nerve cells (neurons) with the brain, but the heart also has its own network of neurons known as the 'intrinsic cardiac nervous system' (ICN). Now, for the first time, a virtual 3D heart has been created that showcases the ICN on a cellular level. It should allow researchers to study the organisation and function of the heart's neurons in intricate detail.

**"The virtual 3D heart showcases the organ's neurons in intricate detail"**

To create the 3D model, which was based on a rat heart, the scientists combined a variety of different techniques. First, thin slices were taken throughout the length of the heart, and microscope images and tissue samples were obtained in the process. These were used to create the foundation of the 3D construction. Next, individual nerve cells were dissected from the rat heart, and genetic information was extracted from them. This data was then fitted onto the 3D model, allowing the scientists to understand the role played by each nerve cell.

"Do separate clusters of the ICN neurons have different functions, or do they work in an integrated way to influence heart health? Now we can address these questions in a way that wasn't possible before," said co-author Dr Zixi Jack Cheng, a cardiovascular anatomist and physiologist from the University of Central Florida College of Medicine.



The 3D model of the rat heart, mapping out all of the neurons

While the research was based on rat hearts, the team says that it should have a long-term impact on human medicine. It could even assist with the burgeoning field of bioelectric medicine, which involves stimulating or manipulating the nervous system to help treat and diagnose various conditions.

The methods used to create this model have been made available via the SPARC programme, so that other teams can build upon the research, potentially leading the way for the development of virtual maps of other organs.

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# Your pocket A-Z tree guide

**Use the Woodland Trust's handy free Tree ID app to help you identify the UK's native and common non-native species, whatever the season**

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Use the map to explore thousands of ancient trees nationwide

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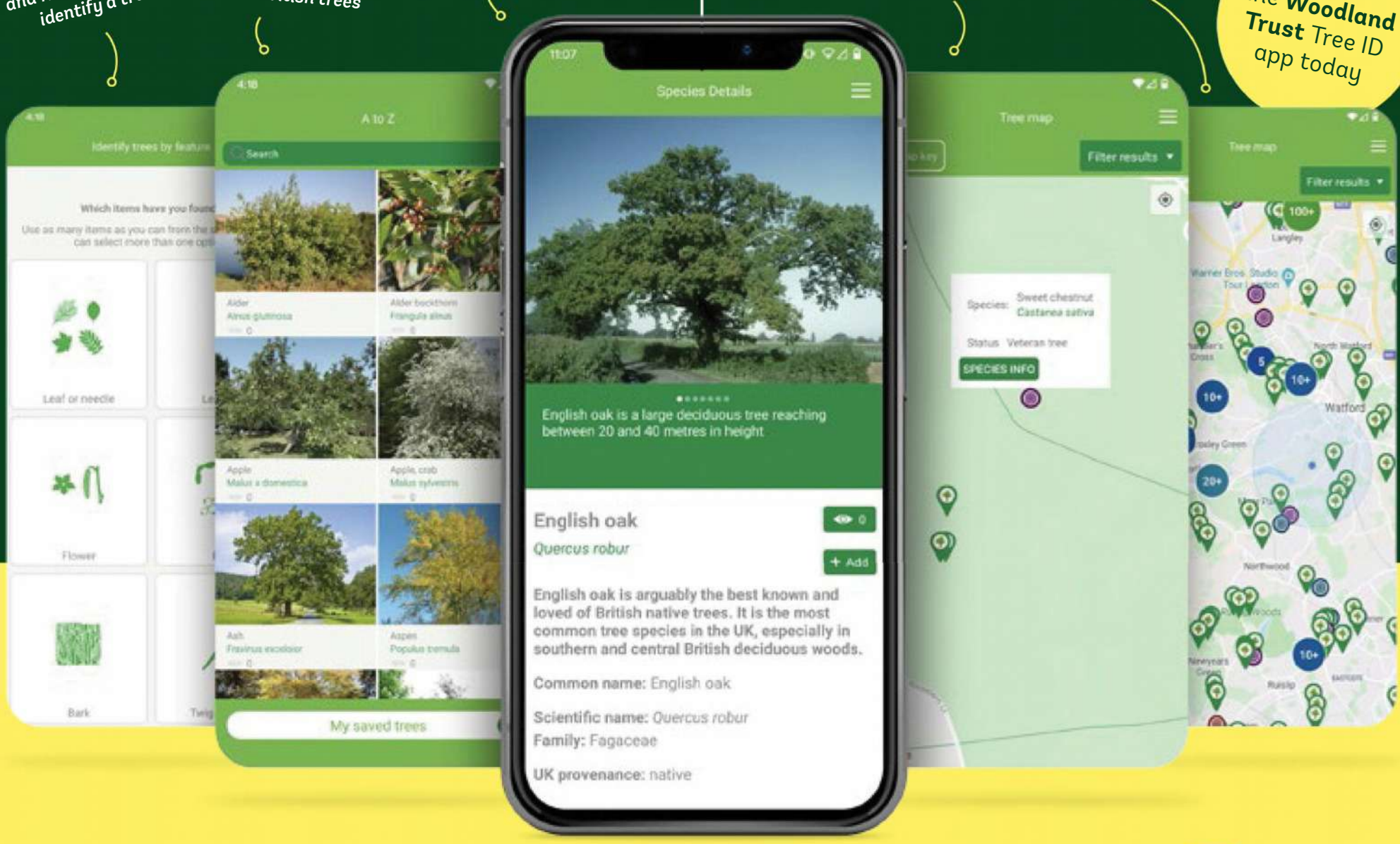


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# GREEN PAPERS

## The environmental stories you need to know

Words: **Jocelyn Timperley**

### LOCUST PLAGUE

Millions of people in East Africa, the Middle East and Asia are at risk of hunger due to rising swarms of desert locusts. The insects are threatening pastures and crops wherever they go. Locusts eat almost all crops, and in one day a swarm covering one square kilometre can consume the same amount of food as 35,000 people.

Just months after Kenya was hit by the worst locust outbreak in 70 years, a second, larger wave is currently causing destruction. In India, farmers already hard hit by the coronavirus pandemic are now battling a massive invasion of the insects, while farmers in Pakistan are suffering the worst plague of locusts in recent history.

**Plastics are a blight on our beaches, but other forms of pollution are also harmful to the marine environment**

OCEANS

# Removing plastic from the ocean is not enough

**Plastic, along with 'invisible' pollutants like heavy metals, oil, gas, pesticides and chemicals, need to be kept out of the sea in the first place**

The problem of ocean plastic pollution, such as plastic shopping bags, discarded fishing nets and microplastics, has received increased attention in recent years.

But other pollutants, including oil, gas, pesticides, antibiotics, heavy metals and industrial chemicals, are also severely impacting the world's oceans, according to a new report from the World Resources Institute (WRI).

"Even though plastic is a hot topic, it is unfortunately just the latest major pollutant to enter the ocean," said Ellie Moss, an ocean plastic expert and co-author of the report.

"I think one of the things that differentiates it from most of the other pollutants is that you can see it. In the other cases it's sort of these invisible pollutants that we don't even recognise as being there. That's

## FOREST HEAT

Tropical forests are carbon sinks, absorbing $CO_2$ from the atmosphere as they photosynthesise. But hotter, drier conditions brought by climate change threatens this ability to hold carbon by decreasing the growth rates of trees and shortening their lifespans, a new study says. What's more, at daily temperatures above a threshold of 32°C, tropical forests start losing stored carbon more quickly, the international team of researchers found. On the bright side, the study also revealed that forest carbon stocks appear to be resilient to temperature increases up to moderate levels of warming, as long as they are also protected from logging and fires.

a huge problem," she added.

The new report, commissioned by the High Level Panel for a Sustainable Ocean Economy, which is convened by 14 heads of state, outlines a range of ways to reduce these different ocean pollutants. In many cases, strategies can tackle more than one type of ocean pollutant at once. "You really do have to look for opportunities to address as many of these pollutants at once as you can," said Moss.

### CIRCULAR ECONOMY

According to the report, part of the solution is exploring how materials can be recaptured and recycled, preventing them from seeping into the ocean as pollutants and instead keeping them circulating in the economy. Developing more eco-friendly materials and chemicals is another important part of the picture.

But there is also a need to simply use resources more efficiently in the first place, the report added, through initiatives such as zero-packaging supermarkets, eliminating single-use plastics and exploring new business models that incentivise the more efficient use of pesticides.

"A lot of people think about 'how do we clean up the ocean' and that's the wrong question," said Moss. "The question is not how do we clean it up, it's how do we stop befouling it in the first place."

Linda Nowlan, who heads the marine programme at West Coast Environmental Law, a legal advocacy organisation in Canada, said that voluntary pledges and activities won't be able to protect people from the rising tide of plastic pollution.

"We need a legally binding treaty to stop the continued growth of plastic production," she said. "There is definitely an urgent need for stronger legal controls on plastic producers and recyclers."

**"Voluntary pledges and activities won't be able to protect people from the rising tide of plastic pollution"**

## INSPIRED EXPIRED

### GREEN STOCKS

Companies with good environmental and social credentials have proven more resilient than others during the economic crisis seen in the first three months of 2020, according to a study led by the Centre for Economic Policy Research.

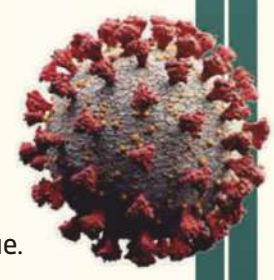
### E-BIKES CUT EMISSIONS

E-bikes could slash transport emissions in the UK, while offering a safer way to commute during the pandemic, said a report from the Centre for Research into Energy Demand Solutions.

### GREEN SNOW

Scientists at the University of Cambridge found that coastal Antarctica is being turned 'green' due to climate change, with the spread of snow algae on the rise as the continent warms.

### CLIMATE CHANGE LOSES SPOTLIGHT



Climate change has been 'swept off the front pages' by coronavirus, Sir David Attenborough has said, calling for a renewed focus on the issue.

## IT'S EASY BEING GREEN

### WALK OR CYCLE MORE

The Intergovernmental Panel on Climate Change (IPCC) has highlighted walking and cycling more as one of the tactics that save energy and could help to stabilise global temperatures. Many car journeys that we make in our daily lives are relatively short. Almost two-thirds of 2-3km journeys in England are made by car, but these journeys could often be made by foot, reducing greenhouse gas emissions and air pollution while helping you stay healthier. For longer journeys, bicycles are an option. Electric bikes in particular are increasingly allowing people to travel further, and offer a boost up steep hills too.

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**Daniel MacArthur** geneticist

Horizons

# First studies from largest-ever human genome database released

**The Genome Aggregation Database has collected 15,708 genomes and 125,748 exomes (the protein-coding part of the genome) to help shed light on how genetic mutations can lead to disease**

### HOW DID THE GENOME AGGREGATION DATABASE (gnomAD) PROJECT START?

I started my lab in Boston back in 2012. At that time, one of the first projects we launched was to begin sequencing DNA from patients affected by severe muscle diseases, like muscular dystrophy.

What became clear was that we desperately needed better databases of normal variation [in genomes] to make sense of the genetic changes that we were seeing in these patients. Imagine if you sequenced the DNA from a patient, and you find a new genetic change there. You need to know whether or not that is a really rare genetic change that is disease-causing, or whether it's actually really common in the population, in which case it's almost certainly not responsible for that patient's disease.

So we set about beginning to build a new database of human genetic variation by taking advantage of a whole bunch of other studies that had been done at the time. These were starting to pull together DNA-sequencing data for a whole variety of different common adult onset disorders, things like type 2 diabetes and heart disease.

### HOW DO YOU COLLECT THE DATA?

We don't actually generate the data ourselves. The gnomAD Project team are data parasites: we take advantage of the data that's been generated by others when they agree to contribute that data to our project. We can then do the hard process of pulling that data together and aggregating it and cleaning it up and then producing this big shared database that can be released to the rest of the world. It is, I think, a testament to the overall generosity of the human genomics community that we've been able to pull together such a large resource through that approach.

### THE DATABASE CONTAINS GENOMES AND EXOMES. WHAT ARE EXOMES?

Exomes are the genes that we know the most about and are also the genes that are the most commonly involved in very rare diseases like muscular dystrophy or severe retinal disease. Exomes are widely used because they are cheaper than sequencing a whole genome.

### HOW COMMON ARE GENETIC VARIATIONS?

There are about three billion base pairs, or letters, in the human genome. If you compare any two humans, we differ at about one in every thousand letters. Everyone has genetic variations. It depends on exactly which ancestry group you're from, but we all carry somewhere between three and six million points of variation across our genomes – points where we differ compared to the person sitting next to us or someone who is unrelated to us. Most of that variation is benign,

GETTY IMAGES

**"You need to know whether or not that is a rare genetic change that is disease-causing, or whether it's really common"**

## EXPLAINER:

DNA is made up of base pairs, or 'letters'. A gene is a particular section of DNA that carries information to make proteins, or instructions for traits and characteristics.

Proteins are large, complex molecules that do most of the work in cells – and they're necessary for the structure, function and regulation of the body's tissues, organs and processes.

A genome is the complete set of an organism's DNA. The 'exome' makes up around 1-2 per cent of the genome, yet does all of the protein-coding. The exome contains the vast majority of disease-causing variants. The remaining 98-99 per cent of the genome is called 'non-coding' DNA.

and a lot of it is quite common, but some is rare. Most of it doesn't have a big impact on our health, but a small subset does. In some people, such as people who suffer from severe diseases like muscular dystrophy, those genetic changes can be catastrophic.

### HOW DO THESE GENETIC VARIATIONS ARISE?

They arise through what we call mutation. When we're born, every one of us carries about 60 to 80 new genetic changes. These are genetic sequence differences that were not present in either of our parents. The rest of the variants that we carry are much older, those are the ones we inherit from our parents. They have also arisen from mutations but they may have occurred many generations ago, potentially thousands of generations ago.

### WHAT MAKES SOME OF THESE VARIANTS BENIGN, AND SOME OF THEM CAUSE DISEASE?

There are a lot of different ways that a genetic change can affect the function of a gene. A gene is composed of lots and lots of pieces called exons. These are the protein-coding bits and they're surrounded by a big island of non-protein-coding DNA. Most of the genes that we understand the best in the human genome are protein-coding genes. Their job is basically to serve as a template for making a specific protein. A good example might a gene called CFTR. This encodes a little protein that pops up into the surface of cells in the lung and is responsible for transporting chloride ions across the cell wall. Usually it does that very well, but in some individuals who have two broken copies of that gene, that transporter can be completely dysfunctional. As a result, they end up with cystic fibrosis. So, these proteins are typically the 'doing molecules' in the cell. They're the bits of the cell that get particular jobs done. These genes are important because they encode all these different molecules that perform these critical chemical functions.

### HOW DOES A GENE BECOME 'BROKEN'?

Usually by introducing what we call a 'stop signal' right in the middle of that protein-coding sequence so that the protein can't be made at all. As a result, that gene becomes non-functional. What's interesting is that these loss-of-function variants are seen in all of us. We all carry about 100 to 150 of these gene-breaking mutations, and most of them don't hurt us. They knock out genes that are either not necessary for life, or they only knock out one copy of the gene and the other copy is enough for us to continue living healthily. But some of these mutations can be really important – either because they result in very severe disease or because they potentially teach us something about the function of that gene. By studying the people who carry these loss-of-function variants, we can learn about what breaking that gene actually does to us. And that, in turn, can tell us what the normal function of that gene is.

**DR DANIEL MACARTHUR**

*Daniel is the scientific lead of the gnomAD Project and director of the Centre for Population Genomics, Garvan Institute of Medical Research and Murdoch Children's Research Institute.*

***Interviewed by* BBC Science Focus *commissioning editor Jason Goodyer.***

Kennedy Space Center, Florida, USA

SPACE

# SpaceX craft completes its landmark flight

**SpaceX makes history as the first private company to design, build and launch a craft to carry astronauts to the International Space Station (ISS), opening up the future for private spaceflight**

**1.** The SpaceX Crew Dragon module and Falcon 9 rocket are prepared for launch in a hangar. To the left are two Falcon 9 boosters that were recovered from a previous launch. SpaceX is the first organisation to recover boosters for reuse, rather than losing them at sea after launch.

**2.** NASA astronauts Bob Behnken and Doug Hurley walk out of the Operations and Checkout building on their way to the launchpad. They are wearing SpaceX's newly designed spacesuits.

**3.** On 30 May, Crew Dragon was launched atop a reusable SpaceX Falcon 9 rocket from Cape Canaveral, Florida.

**4.** Two minutes and 40 seconds after the launch, the Falcon 9 rocket detached from Crew Dragon before falling back down to Earth. It fired its boosters to land safely on an autonomous droneship waiting in the Atlantic Ocean.

**5.** Behnken and Hurley will now spend up to four months living and working on the ISS alongside the three other current inhabitants – NASA astronaut Chris Cassidy and Russian cosmonauts Anatoly Ivanishin and Ivan Vagner – before Crew Dragon will undock and carry them back to Earth.

**6.** After a 19-hour journey, the Crew Dragon spacecraft attached itself to the ISS, using its fully autonomous docking system.

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# REALITY CHECK

SCIENCE BEHIND THE HEADLINES

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REVIEW

## RETURN TO WORK: DOES COVID-19 MARK THE END OF THE OFFICE?

As people head back to work, organisations are making drastic changes to the office layout, putting up dividers, two-metre distancing markers and hand-sanitising stations. But is it enough to keep us safe?

# "If just one person comes to work sick, then they can contaminate over 50 per cent of the office surfaces in less than four hours"

BBC *Visit the BBC's* Reality Check *website at* **bit.ly/reality_check_** *or follow them on Twitter* **@BBCRealityCheck**

Flexible hours and working from home have been on the rise for a number of years, with around 1.7 million people out of the UK's 32.6 million in employment reporting that they worked mainly from home in 2019, compared to just 884,000 working from home in 2008. But since the coronavirus pandemic and at the UK government's request, it's believed that approximately 44 per cent of working adults – roughly 14.2 million people – have turned their living spaces into a home office.

In 2019, Kelly Reynolds, a professor of public health and environmental science, published a paper looking at the way a virus spreads within the office environment. Reynolds and her colleagues at the University of Arizona found that simple hygiene measures or interventions, like providing hand sanitiser and disinfection wipes, could result in an 80 per cent reduction in the risk of respiratory and diarrhoeal illnesses.

Throughout the COVID-19 pandemic, Reynolds has been helping businesses with infection control and has been advising public services on how to safely re-open.

## HOW DOES A VIRUS SPREAD AROUND THE OFFICE?

"If just one person comes to work sick, they can contaminate over 50 per cent of the office surfaces, and their co-workers' [spaces], in less than four hours," says Reynolds. "The typical route of transmission is from an infected person's hands to surfaces that are touched by multiple people."

This hand-to-surface-to-hand transmission enables a virus to spread quickly in an office setting. That's why the worst offenders are shared areas, such as the kitchen and toilets, and things touched multiple times a day, like doorknobs and lift buttons, says Reynolds. The most contaminated site? The handle to the refrigerator door.

## HOW CAN EXTRA HYGIENE MEASURES HELP?

Reynolds's study found that giving each employee hand sanitiser, tissues and surface-disinfecting wipes, along with stocking hand sanitiser in common areas like conference rooms and shared facilities, significantly reduced the risk of virus transmission. Just making these products readily available helps to increase their use, she says.

GETTY IMAGES X2

"Having a hygiene intervention in place is a must to reduce germ transmission in the workplace," stresses Reynolds. "While still maintaining social distancing as much as possible, other infection-control methods include installing plexiglass barriers between workers or at popular client interface areas, or requiring masks, to reduce the transmission of aerosols that may transmit coronavirus."

## WHAT OTHER CHANGES WILL HAVE TO BE MADE?

Businesses will have to go further than just handing out sanitiser. "As workplaces re-open, it is important to do a site-specific assessment of the areas most prone to contamination," says Reynolds, which means identifying high-touch surfaces and the places where most people congregate throughout the working day.

"Increasing ventilation rates and fresh air exchanges in buildings will help to dilute indoor air contaminants. Remember, too, that if buildings have been shut down for a week or more, it is necessary to flush stagnant water from taps to reduce exposure to deadly bacterial pathogens, such as *Legionella*, that may have grown over time."

There's also a lot to be said for open and upbeat communication on the part of the employer. "Signage with positive messaging about proper hand hygiene and disinfection practices serves to inform employees and customers that your workplace has a culture that values good hygiene and health," says Reynolds. "Administrative controls, such as staggering work schedules or work at home options will also aid in social distancing. Many ▶

**ABOVE** Simple hygiene measures, like supplying office staff with hand sanitiser in communal areas, can drastically reduce risk of illness

## TOP 5 DIRTIEST SPOTS AROUND THE OFFICE

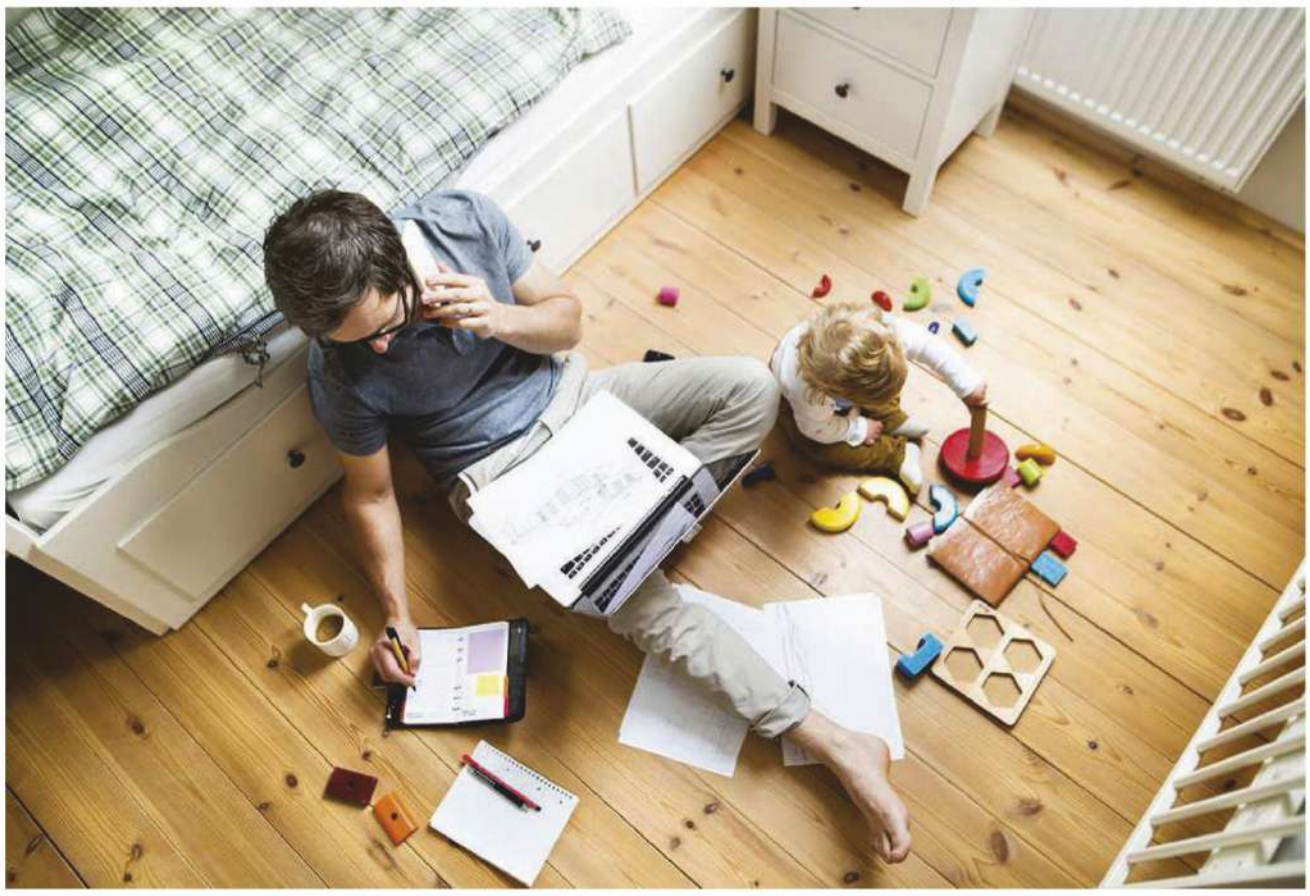
Refrigerator door handle

Handles to kitchen doors and cupboards

Kitchen taps

The pushbar to exit the building

Soap dispenser in the women's toilets



**ABOVE** Once the pandemic is over, some companies may allow employees to work from home more often in order to reduce risk of illnesses

businesses are doing daily wellness checks – checking temperatures and asking simple health assessment questions such as 'How are you feeling today?' and 'Are you, or is anyone in your family, feeling ill?'

"Having flexible sick policies is important in encouraging sick employees to stay home and not spread their illness to others," Reynolds explains.

### WHAT CHALLENGES DO WE FACE IN DESIGNING A MORE HYGIENIC OFFICE?

Reynolds explains that we don't yet know everything we need to about the novel coronavirus in order to rethink our offices.

"We are learning more about this virus every day. Uncertainties related to how far it can spread or how long it survives on surfaces are still being researched. Following best practices in infection prevention, however, can dramatically reduce our risks to SARS-CoV-2 and other pathogens, like influenza and norovirus. Maintaining these safeguards may help to prevent the next outbreak."

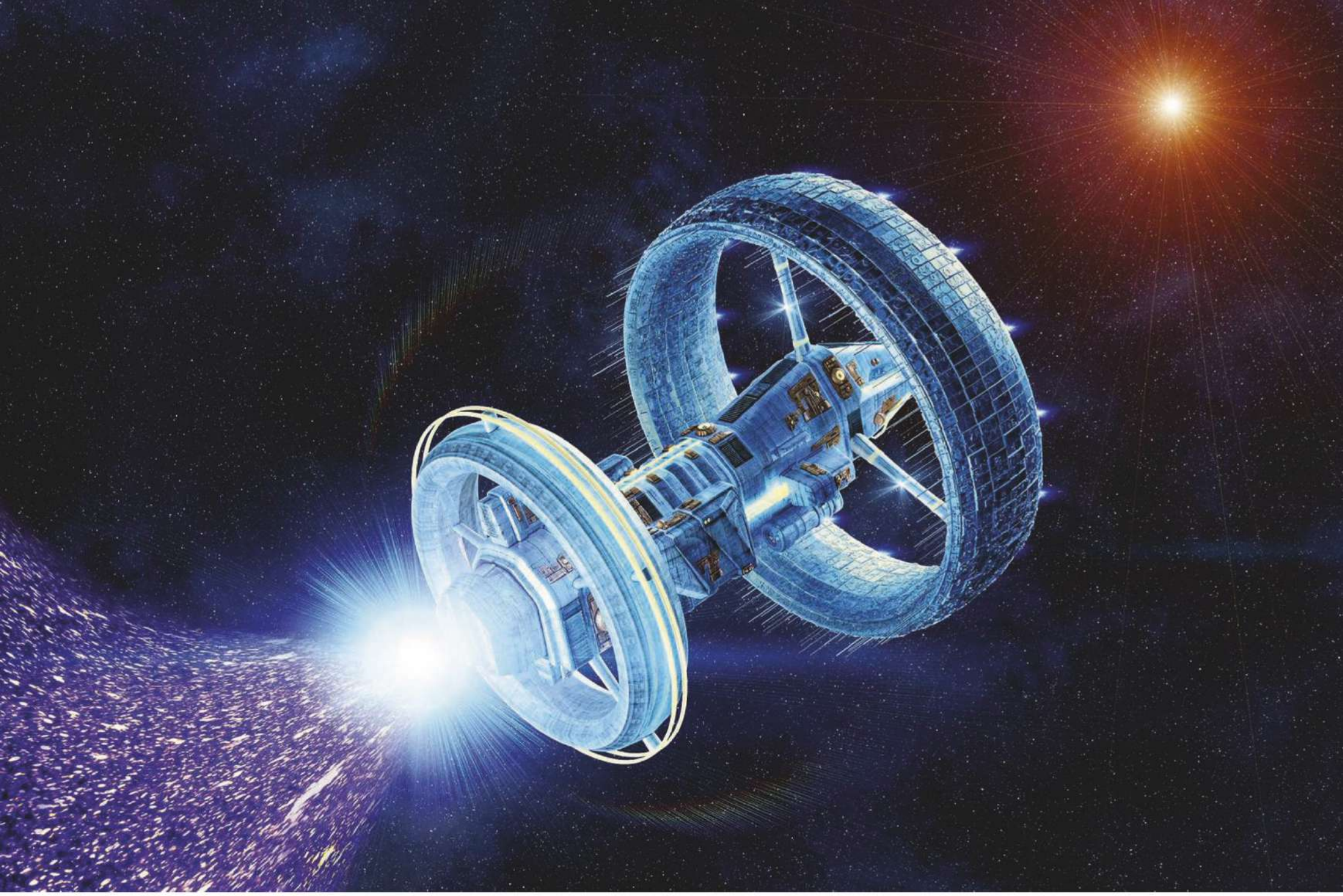
### SHOULD WE ALL CONTINUE WORKING FROM HOME, THEN?

With more of us setting up working spaces in our own homes, organisations will be considering if returning to the office is the right choice for their employees' health. But what is the more hygienic option?

"Office buildings are typically worse [for disease transmission] because you have less control there to keep the entire environment clean and sanitised," says Reynolds, "but we also find that viruses spread efficiently in home environments, where people tend to let their guard down. Maintaining proper handwashing and surface-disinfecting routines at home, and isolating any sick family members to limited areas in your house as much as possible, will help combat this."

by AMY BARRETT
*Amy is the editorial assistant at* BBC Science Focus.

REFRIGERATOR BY FAHMIONLINE, DOOR HANDLE BY CHUNK ICONS, MIXER TAP BY VECTORS MARKET, PUSH BY LUIS PRADO AND HAND WASH BY ZOO STUDIOS ALL FROM THE NOUN PROJECT



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ANALYSIS

# FASTER-THAN-LIGHT TRAVEL: IS A WARP DRIVE REALLY POSSIBLE?

**A NASA scientist recently released a report analysing the feasibility of a warp drive as a means of faster-than-light travel. Could this *Star Trek* technology really be possible?**

In the universe of *Star Trek*, on 5 April 2063, humanity ventures out into the Galaxy on the first ship capable of faster-than-light travel, the *USS Enterprise*. The newly invented 'warp drive' not only lets humans explore the cosmos, but also attracts the attention of Vulcans and brings about our first contact with an alien species.

It's been 54 years since we were first introduced to the *USS Enterprise*, and many of the futuristic technologies from *Star Trek* have since been invented, from handheld communicators to universal translators. A warp drive is the next obvious choice: Voyager 1, which has travelled further from Earth than any spacecraft, took nearly 35 years to leave the Solar System. Not exactly handy for interstellar travel.

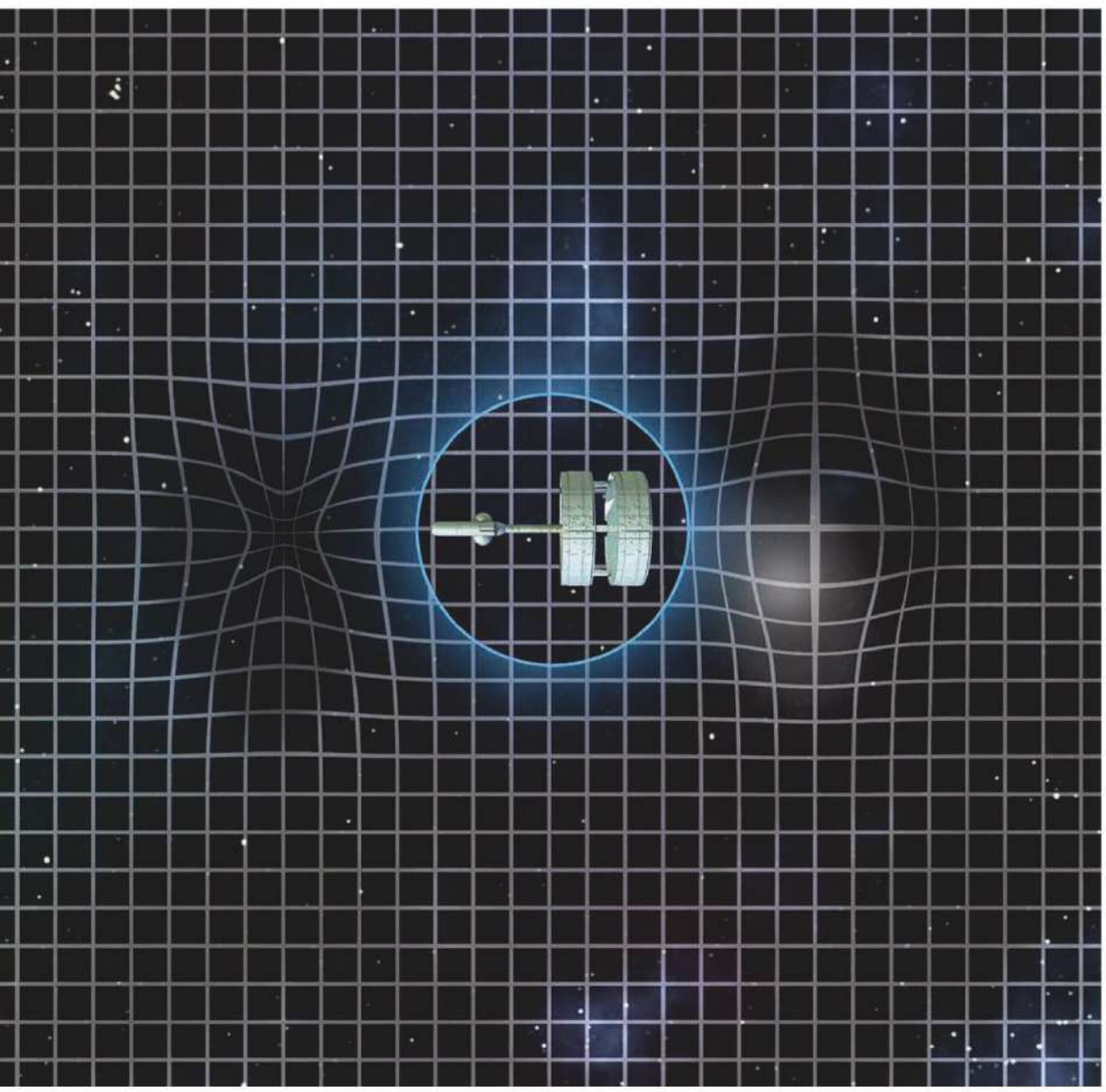
Luckily for humanity, theoretical physicists have been working on it. In May 2020, NASA scientist Dr Harold 'Sonny' White released an internal feasibility report discussing the technology from the point of view of 'early mission planning'.

## FASTER THAN LIGHT

The first scientific theory of warp drives came about in 1994, when theoretical physicist Dr Miguel Alcubierre used Einstein's theory of General Relativity to develop a framework that would allow faster-than-light travel within the confines of the laws of physics. The key that makes it possible is that, technically, the ship itself doesn't travel faster than light.

"What a warp drive is doing is basically saying that there is no law of physics that says space-time itself can't go faster than the speed of light," says Dr Erin Macdonald, astrophysicist and science consultant for *Star Trek*. "And so the concept of a warp drive is to say, all right, let's take our ship, let's build a bubble of space-time around it, and then we'll have that propel us faster than the speed of light." It's similar to the idea of a car driving inside a moving train: someone standing by the tracks would see the car travelling much faster than its top speed.

According to the theory of General Relativity, the Universe is a flat sheet of space-time which is warped by any object with mass. "We think of a bowling ball on a trampoline and that bowling ball dips the trampoline down," explains Macdonald, "and that's what mass [the ball] does to



**ABOVE** The Alcubierre drive works because the ship is surrounded with a bubble of space-time, which is compressed in front of the ship and expanded behind it

space-time [the trampoline].” This distortion of space-time is what we experience as gravity.

The Alcubierre drive uses the same concept. The ‘bubble’ surrounding the ship is an area of space-time that is compressed in front of the ship and expanded behind it. As with gravity, you could create this distortion using a large amount of mass. Alternatively, thanks to Einstein’s $E = mc^2$ (energy is equal to mass, multiplied by the speed of light squared), you could equally use a huge amount of energy.

Inside the bubble, space-time is completely flat, meaning the space travellers wouldn’t notice any strange, relativistic effects. The result is that the bubble of space-time is hurled across the Universe, with the travellers sitting comfortably inside their ship, speedometer still reading the same number.

Unfortunately, actually creating a warp drive is even harder than it sounds. “You have to have a very, very large amount of energy,” says José Natário, associate professor in mathematics at the Instituto Superior Técnico at the University of Lisbon.

“To have the deformation that you need for this kind of thing to work, you’d need much, much more energy than the Sun or the Galaxy,” he says. “But also, it’s negative energy.”

Negative energy is not something that we can currently create – certainly not in the quantities needed to power a warp drive. How could energy be negative at all? One way to think about it is to consider a particle with negative mass. These particles would react to gravity in the exact opposite way to particles of positive mass. Instead of being pulled towards a planet or star, they would be thrown away.

“If we had some sort of component like that where we had a negative mass, whatever is keeping that mass together would be that negative energy,” says Macdonald. This isn’t a problem that will go away with refining the idea, either: Natário proved mathematically that any form of warp drive will require negative energy.

## IMPOSSIBLE MISSION?

Natário believes there’s an even greater problem with the concept of the Alcubierre drive. Imagine a supersonic aircraft travelling faster than the speed of sound. You don’t hear the aircraft until it has already gone past, because the sound waves can’t keep up. The warp drive experiences the same effect with light waves, meaning there is no way to send a message ahead of you.

“I call it the ‘you need one to make one’ problem,” says Natário. How do you create the warped space-time geometry around your ship? First, you would need to send a signal ahead of you to ‘tell’ space-time to warp, Natário says. “To make it go faster than light, you need something that would be going faster than light to begin with so that you’d be able to communicate outside the horizon.”

These two problems – combined with the slight issue that the travellers would be bombarded with incredibly high-energy radiation – are the downfall of a warp drive, Natário believes. “The bottom line is, in my opinion, it’s completely impossible,” he says.

Macdonald is more hopeful. “I’m an eternal optimist with this because I want to join Starfleet,” she says. “The way I think about it is it’s like we never know what’s going to come down the pipe with some of these weird, exotic, fun thought experiments.

“I agree at this stage, right now, it’s a fun thought experiment. But that’s not to preclude some massive discovery that may happen that we can’t predict.”

by **SARA RIGBY**
*Sara is the online assistant at* BBC Science Focus.

## DISCOVER MORE

**ON THE PODCAST** *Visit **bit.ly/erin-macdonald** to listen to an interview with Erin Macdonald on the science of* Star Trek.

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COMMENT

# GAMING IN LOCKDOWN: WHY ARE SO MANY PEOPLE PLAYING *ANIMAL CROSSING*?

**It sold more digital units in its first month of release than any other video game in history. What makes *Animal Crossing: New Horizons* such a compelling game to play?**

As far as Nintendo games go, *Animal Crossing* isn't perhaps as well-known outside of gamer circles as series such as *Super Mario*, *Pokémon* or *The Legend Of Zelda*. And yet the latest instalment, *New Horizons*, has become something of a phenomenon in this worrying new world we find ourselves in. If you haven't already come across it, *New Horizons* is a life-simulation game, a more easygoing counterpart to earlier titles like *The Sims*. You start off by purchasing a getaway package to a deserted island, armed only with a tent and a few basic tools to tend to the land. Although there's a basic storyline to follow, what you do in your newfound escape is up to you. Among other things, you can go bug-hunting, try to catch rare fish, excavate for fossils, design your home, create elaborate gardens, invite friends over for a catch-up, or stare at the night sky, waiting for shooting stars. There's no endgame, no final boss: this is your own little world, to do with as you please.

In part, this is why *New Horizons* has been such a runaway success. Launched towards the end of March, it came out at a time when we were all finding ourselves confined to our homes, unable to visit our friends and loved ones, and generally feeling as though we were losing control of our day-to-day lives. Along came *New Horizons,* and offered sanctuary: a literal faraway island where we could escape from our worries and impose a little order on some small aspect of our lives. It sold five million digital copies in the first month after its release,

**"It's a carefully crafted game, designed to be soothing, social and imaginative, which happened to come along when we needed it most"**

**ABOVE**
The freedom to play *Animal Crossing* however you like, without worrying about levelling up or beating bad guys, is part of the secret to its success

more than any other computer game in history. By early May, it had sold over 13 million copies worldwide – more than its predecessor, *Animal Crossing: New Leaf*, sold in six years. It hasn't just captured the imaginations of kids and teens either – according to Nintendo, one of the main player demographics is people in their 20s and 30s, looking for a nostalgia hit by playing the latest iteration of a game they first encountered in their youth. And by the company's estimates, some 40 per cent of sales to date have been to female players.

## PUSHING BUTTONS

It's not just about timing and escapism though – *New Horizons* hits some basic psychological buttons. One of the most influential theories about human motivation is known as Self-Determination Theory. First developed in the 1980s by psychologists Dr Edward Deci and Dr Richard Ryan, Self-Determination Theory suggests that while some behaviours are driven by external motivation (say, to gain rewards such as money or praise), others are shaped by more intrinsic forms of motivation – that is, we do some things simply because we enjoy them. Intrinsic motivation is built on the foundations of three basic human needs: autonomy, competence and relatedness. Autonomy relates to the need to experience freedom and choice in the activity you're engaging in, and competence refers to the need to be good at activities, and exert control over them. Relatedness, unsurprisingly, refers to our need to be connected with other people.

Central to Self-Determination Theory is the idea that intrinsic motivation is a fundamental underlying factor for most forms of play – games included. Since the early 2000s, a wealth of research has shown that video games which satisfy these three basic needs also tend to be the ones that are the most successful. If it's an intuitive game that's easy to pick up and master, one which gives you freedom to do as you please, and allows you to interact with and connect with other players in a meaningful way, then chances are it's going to be popular.

*Animal Crossing: New Horizons*, while not perfect, ticks all of those boxes. It doesn't require a steep learning curve. Moreover, its open-ended nature means that most activities you choose to do in the game you do so for the intrinsic value of doing something relaxing, positive or constructive. You don't need to worry about more extrinsic rewards like 'levelling up'; if you don't want to spend your time fishing, for example, it won't negatively impact your gaming experience. And with the ability to invite friends to your island, or visit other people's, it offers a way to stay connected.

So, why is *Animal Crossing* so popular right now? There's no special secret. It all just boils down to the fact that it's a carefully crafted game, designed to be a soothing, social and imaginative experience, which happened to come along just at the point when we needed it the most. **SF**

by **DR PETE ETCHELLS** *(@PeteEtchells)*
*Pete is a psychologist and science communicator, based at Bath Spa University. He researches the short- and long-term psychological effects of video games.*

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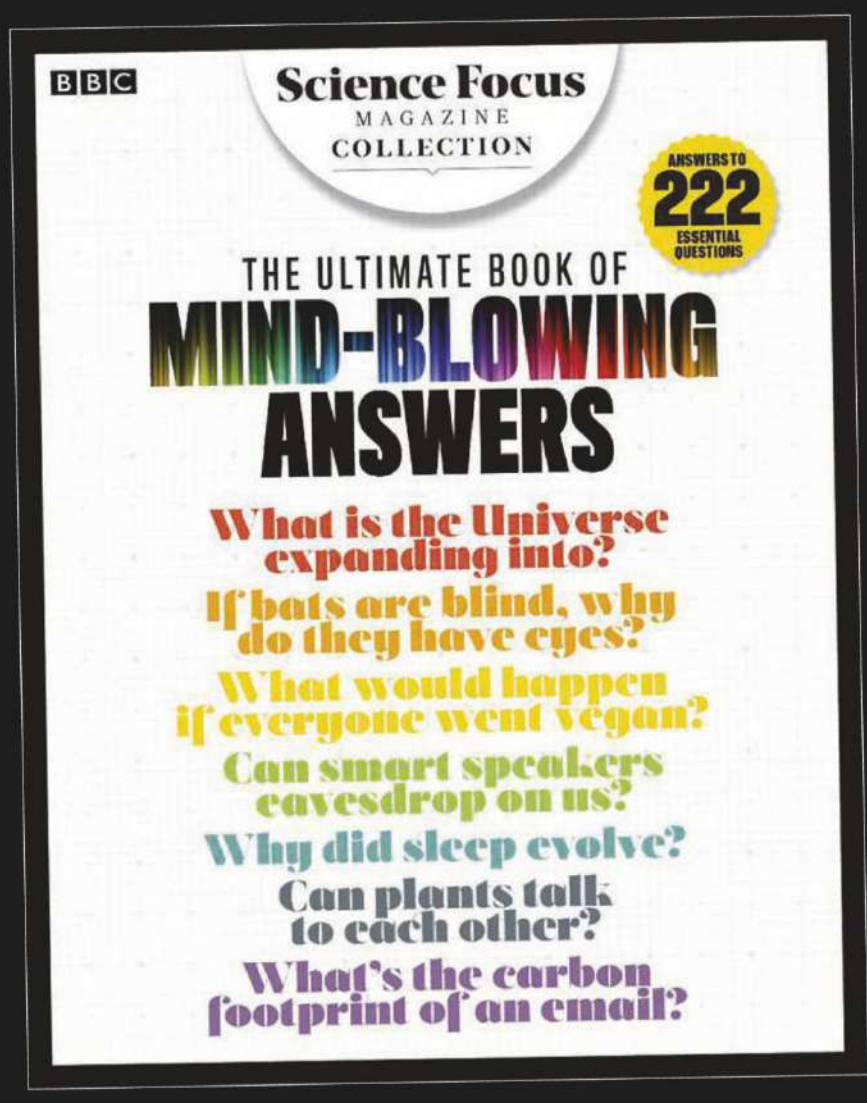
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# INNOVATIONS

## PREPARE YOURSELF FOR TOMORROW

The HaptiRead system has 256 tiny 'speakers' that send ultrasonic waves to a user's hand to form Braille letters

TOP ACCESSIBILITY TECH

### Tactile Pro

The Tactile Pro is the first tablet to be made for blind users. It can turn text and images into Braille, and even supports document editing, internet browsing and gaming.

### Logitech G Adaptive Gaming Kit

Built with Microsoft, the Logitech adaptive gaming kit deconstructs the Xbox controller to make a system that can be laid out in any configuration that meets the player's needs.

### SEED cane

This smart walking cane uses infrared sensors to detect nearby obstacles, connects to a smartphone and can guide the user wherever they want to go using in-built GPS.

ACCESSIBILITY

# Tech without touch

## Haptic technology uses ultrasound waves to create Braille out of thin air

A new form of haptic technology has been designed that gives blind people the sensation of reading Braille, without having to touch any surfaces.

The device, called the HaptiRead, was developed by researchers from the University of Bayreuth, Germany. They hope that the HaptiRead could be used by blind people out in public, for reading departure times at a bus stop or using a cashpoint, for example.

Haptic devices work by simulating physical sensations. For example, if you hit a wall while playing *Mario Kart*, your controller will vibrate. Or, in more sophisticated devices, ultrasound waves are used to push darts of air at you which feel solid enough when they reach your skin, making the invisible into something physical. The HaptiRead uses the latter technique. It has been built from hardware called Stratos Explore, made by a company called Magic Leap that specialises in haptics and gesture controls.

**"MID-AIR HAPTIC INTERFACES COULD PROVIDE A MORE HYGIENIC ALTERNATIVE TO TOUCHSCREEN DISPLAYS"**

The HaptiRead device includes 256 ultrasonic transducers – tiny speakers that emit ultrasound waves in the direction of the user's hand. One ultrasonic wave on its own can't be felt by human touch, so multiple waves are pointed at one spot to create the feeling of pressure on the skin. Using programming software, the researchers told the HaptiRead to create these points in the shape of a Braille character.

The ability to create the feeling of interaction without any physical touch has uses that extend beyond accessibility. "Due to the current pandemic, we all have become more conscious about physical interaction with different interfaces, especially in very frequented public spaces," says Viktorija Paneva, one of the researchers on the project. "Mid-air haptic interfaces, like HaptiRead, could indeed provide a more hygienic alternative to physical and touchscreen public displays that everyone can benefit from. For example, to choose a product from a vending machine without physical contact."

However, the researchers stress the need for further investigation before we see HaptiRead on the streets. But, with more development, Paneva believes the possibility of using such a system in the next few years is quite realistic.

The researchers hope the device could be installed on cashpoints or transport timetables, to aid with accessibility

EDUARDO ESQUECHE LARRABURE

ON TEST

# IPAD PRO WITH MAGIC KEYBOARD

# Could this tablet replace your laptop?

**The iPad Pro, with powerful specs, spectacular display and the newly added Magic Keyboard, is making a strong bid to become your next personal computer. Daniel Bennett finds out if it's up to the job...**

The iPad Pro feels like it's from the future. It's the kind of technological alchemy that only a handful of tech companies seem to manage. The hardware is so well-designed, and the interface so intuitive, that there's just no friction when you use it – nothing slows you down.

For all its elegance, the iPad Pro has always felt a little too glam and a little too workshy to really earn the 'Pro' moniker it carries. But with the arrival of the new Magic Keyboard, complete with a trackpad, can it finally become a tool that helps you be more productive?

### Is it different from a laptop?

Laptops have had keyboards and trackpads for aeons now – so what's the big deal? Well, it's the way Apple's touchscreen interface, the trackpad, the Apple Pencil and Magic Keyboard work together that makes the iPad Pro different.

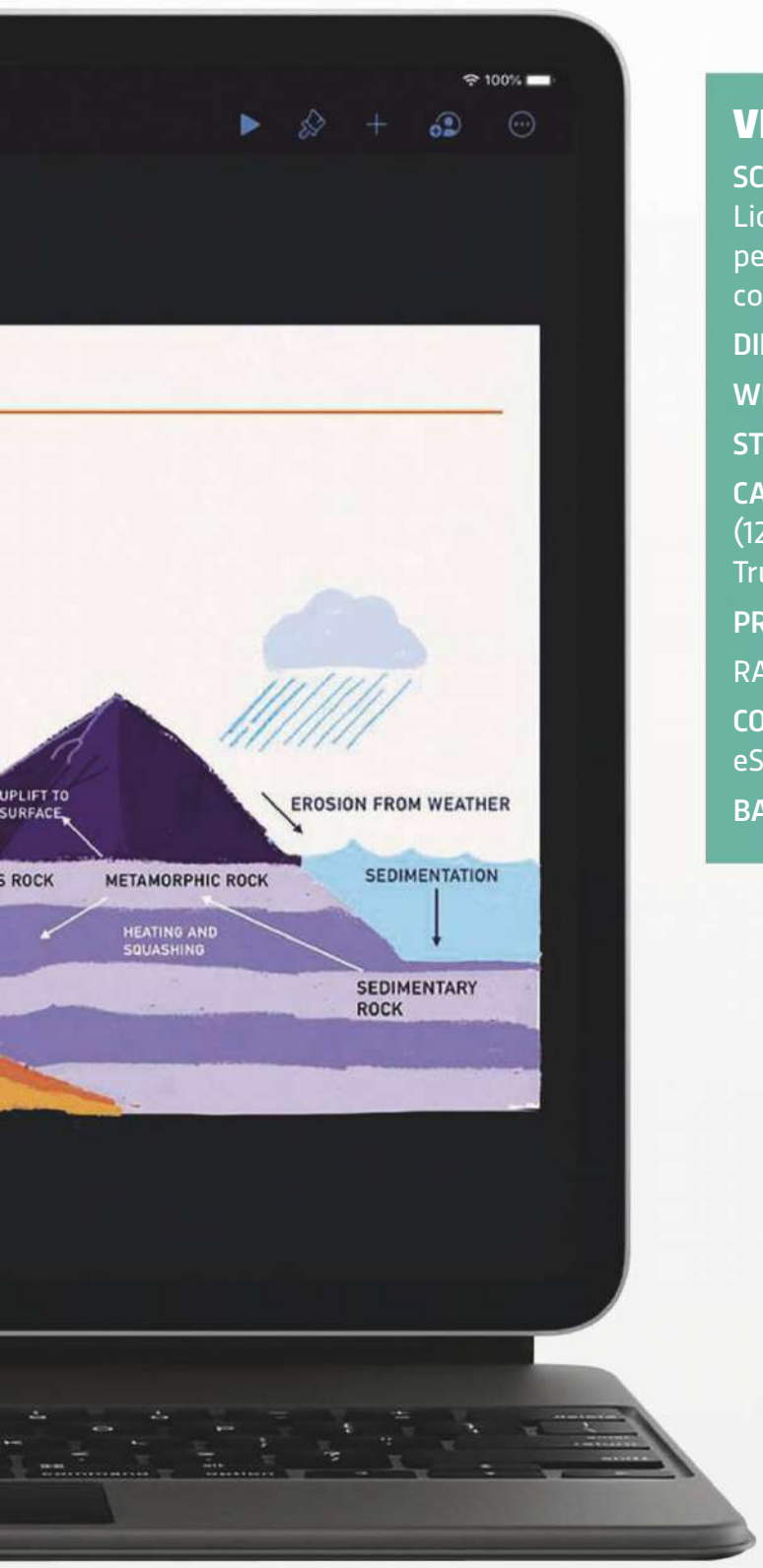
First, the trackpad offers the finer controls needed to do most of the jobs I use my laptop for. I can now write quickly, scan audio files, edit images and even manage video editing. Add in Apple Pencil and you can annotate documents by hand, snip out images or scribble down notes. Then, layer on top the ability to pinch and zoom, swipe between apps and manipulate controls with your hands, and you start to see how the iPad Pro becomes something more than a laptop. Of course, Windows tablets have done this for a while, but nothing feels quite as slick as Apple's iPad OS.

Ultimately, this iPad is a hybrid that pulls off the neat trick of feeling like a different device depending on the task at hand and the software you use. At my desk, writing this review, it feels just like a laptop. But when I proofread, I lift the tablet off the mount, sit on the sofa, and use the Pencil to jot down notes on the digital pages. In the evening, it becomes my personal TV, when I want to watch a series my other half isn't into. Plus, the floating hinge design is lightweight but unshakeable. It holds the iPad Pro aloft at a range of angles, and you can't shake the tablet off its magnetic mount – we tried it so you don't have to.

**"ULTIMATELY, THIS IPAD IS A HYBRID THAT PULLS OFF THE NEAT TRICK OF FEELING LIKE A COMPLETELY DIFFERENT DEVICE DEPENDING ON THE TASK AT HAND"**

### What can't you do?

If you like having multiple windows strewn out across your screen (I do), then you'll be disappointed. Two or more 'windows', can be open at once, but you'll mostly use one app at a time. In practice, the single-mindedness keeps distractions (email, Twitter – I'm looking at you) out of sight, and genuinely improved my focus.




## VITAL STATS

**SCREEN:** 12.9-inch, 2,732 x 2,048 Liquid Retina display (264 pixels per inch) (11-inch available, but not compatible with Magic Keyboard)

**DIMENSIONS:** 280.6 x 214.9 x 5.9mm

**WEIGHT:** 641g

**STORAGE:** 128GB, 256GB, 512GB or 1TB

**CAMERA:** 12MP wide, 10MP ultrawide (125° field of view) and LIDAR, 7MP TrueDepth selfie camera

**PROCESSOR:** Apple A12Z Bionic

RAM: 6GB

**CONNECTIVITY:** Wi-Fi 6 (4G optional, eSim), Bluetooth 5, USB-C

**BATTERY:** 10-hour web browsing

The magnetic floating hinge design holds the tablet firmly – there'll be no broken toes here

You're also at the mercy of the software available on the App Store. There's a tonne of mainstream apps, but niche titles are lacking for now. For example, although Adobe Illustrator and Photoshop are available, InDesign, which is used to create editorial pages, isn't there yet. For most people this will be a minor foible, but it's worth checking that the software you need is there before you buy the device. This would also give me pause for thought before recommending the iPad for a student heading to university. In the sciences, there's invariably some odd program that you might need once your course gets underway.

The iPad Pro works well as both a tablet and laptop, making it ideal for various different tasks

### Any other features?

The latest iteration of the iPad Pro has LIDAR built in. This is the tech that helps autonomous cars see the world. The iPad emits tiny points of light and as they bounce off your surroundings, it measures how long it takes for the light to return. This measurement means it can calculate exactly how far away everything is and accurately map the world around you. Using this, you can measure rooms and surfaces at a glance.

But there are bigger fish to fry. With LIDAR, augmented reality – where virtual objects are brought to life in the real world – is seamless. For example, just turn on the Ikea app and find out what that armchair might look like to scale in your living room. Better yet, use the Adobe Air app to create your own augmented reality experience. This is what many pundits say will form the future of computing, so get the kids learning it now.

### So, should I buy one?

A 12.9-inch Pro, together with the Apple Pencil and Magic Keyboard, will set you back at least £1,400. That's Macbook Pro money, so it needs to perform exceptionally well. And it does.

That said, there are some barriers that might stop it being your one and only computer. As mentioned, the apps won't meet everyone's needs. One USB-C port on the tablet and one on the Magic Keyboard means you'll need expensive converters to connect all the equipment you might need. A headphone port would have been nice, but those days seem to be long gone. And finally, the file architecture can be a little restrictive for anyone used to Macs and PCs.

Those concerns aside, the iPad Pro – together with the Magic Keyboard and Apple Pencil – is the first iPad I can see a real need for. As a hybrid, it's able to transform for the task at hand. If the iPad Pro is anything to go by, in the future, machine interaction will be smarter and more natural than ever before.

In the end, the whole package is a joy to use in a world where impressive computers have become fairly mundane.

# Ideas we like...

→
## An ultralight e-bike that's easy on the eyes

Taiwanese company Gogoro has taken the motor, batteries and sensors of an e-bike and tucked them into a hub on the back wheel to streamline the design and create what it calls the 'sports car' of the e-bike world. The carbon fibre frame keeps the weight down to 12 kilograms, while helping to soak up the bumps and potholes of city streets. It has a battery-assisted maximum range of 88 kilometres (55 miles), can recharge in 2.5 hours and will lock down the motor itself when you park up. Oh and it's priced like a sports car too.

Eeyo 1
From $3,899 (£3,101 approx), eeyo.bike

↑
## A camera designed for YouTubers

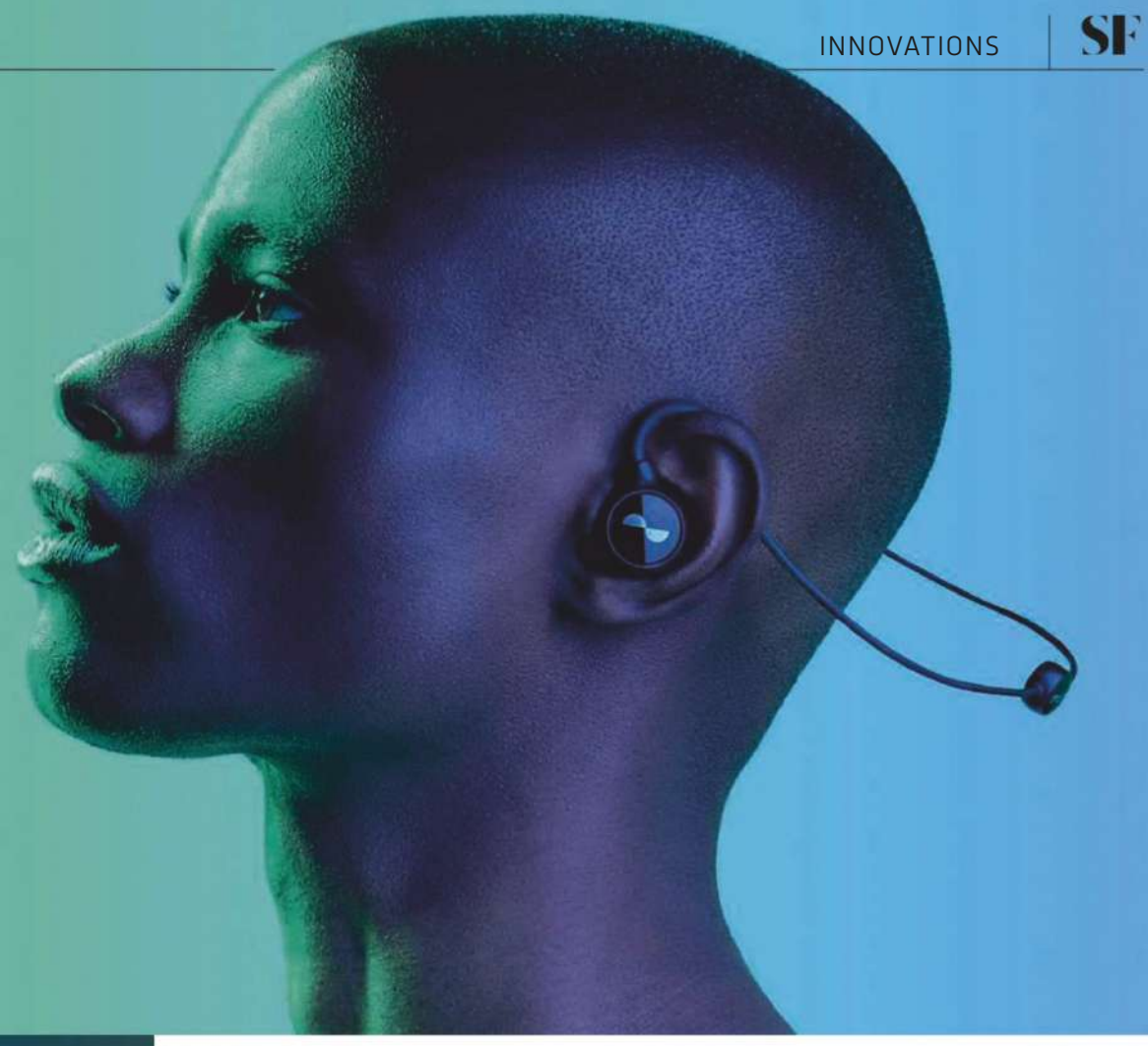
Sony's latest pocket camera is built for vlogging. It has a whip-smart autofocus, a lens optimised for selfies (well, video ones at least) and a side-flipping screen that lets you see what you're filming when you're talking to camera. Add a microphone to the hotshoe (the mounting point at the top of the camera) and you've got the ideal camera for a budding YouTube star.

Sony ZV-1
£699, sony.com

↓
## A tiny games console

Normally we're not one for nostalgia, but this almost-keyring-sized Game Gear Micro hits us right in the reminiscence bump. The teeny, tiny console measures in at 80 x 43 x 20mm, with a 1.15-inch display. It's got a small mono speaker, a headphone jack, and charges off USB or it can be powered by two AAA batteries. There are four colours available, each with its own set of four games. And if you're wondering how on Earth you could play games on such a small screen, then this probably isn't for you – but it does come with a magnifying glass attachment like the original…

Game Gear Micro
¥4,980 (£36 approx), sega.com



## → Earphones that look after your lugs

What if your earphones could give you a hearing test and tune your equaliser to reflect the frequencies you are most, or least, sensitive to? That's the idea behind the Nuraphone, which we first tested a few years back in headphone format. The company has now shrunk their clever tech and shaped it into a set of Bluetooth earphones called the NuraLoop. They're packed full of all the other tech you'd expect – like active noise-cancelling and touch controls – but we love the extra smart touches, like the magnetic analogue jack that lets you connect to your earphones with wires when you need it.

NuraLoop
£199, nuraphone.com

## ↑ An affordable OLED TV

**OLED display technology has been around for a while now, but it's generally expensive to manufacture and buy. That said, I'm a big fan of the tech because OLED panels provide a life-like picture quality, thanks to the unique way they work. In a traditional LED display, a light is shone through coloured crystals to create a picture. The light means that dark areas are never truly black, reducing the contrast that can be achieved. In an OLED display, the coloured crystals themselves light up as electricity passes through them, meaning that black areas of the picture can stay that way, generating a truly realistic picture. LG's new 48-inch model is one of the cheapest we've seen, and it doesn't scrimp on features or specs either.**

LG OLED 48CX
£1,499, lg.com

## ↓ Steamed toast

Okay, so if I spent $300 (£238) on a toaster, my bank might call me to check for fraud. But now I've discovered the Balmuda steam toaster, my toast has started to taste like plywood. Balmuda, a Tokyo-based tech company that specialises in perfecting kitchen appliances, says its oven uses "steam technology and precise temperature control to bring out the best in every kind of bread". Well, now I feel guilty for letting down my bread. Anyway, the oven turns five millilitres of water into steam, and wafts it over the bread in three temperature phases. The first low-temperature phase 'restores interior fluffiness', the second starts the Maillard reaction, turning the bread golden, and the final phase (220°C) turns it brown. It can do the same for other foods too – meaning reheating yesterday's pizza won't dry it out.

Balmuda The Toaster
$300 (£238 approx) us.balmuda.com

# SPRING TO LIFE

**GRAND PRISMATIC SPRING, YELLOWSTONE NATIONAL PARK, WYOMING, US**

Yellowstone's Grand Prismatic Spring is the largest hot spring in the US, and it boasts a veritable rainbow of colours. Hot water bubbles up through a crack in the Earth's crust, supplying the spring. Very little can survive in the centre of the spring, where temperatures can reach nearly 90°C, so the water here is a pure blue. But away from the centre, colourful, heat-loving bacteria begin to thrive, and the spring's concentric rings of temperature create different niches. The colours come from the photosynthetic pigments, such as chlorophyll and carotenoids, that the bacteria use to manufacture energy from sunlight. Carotenoid-rich *Synechococcus* bacteria are responsible for the innermost yellow ring, while slightly further from the centre, *Synechococcus* rubs shoulders with other carotenoid-containing bacteria, giving more of a tangerine colour. Closer to land, where the bacteria are more diverse still, the cocktail of pigments creates a rusty Martian hue.

# THE MOST COLOURFUL SIGHTS ON EARTH

**LONG-DISTANCE TRAVEL IS CURRENTLY OFF THE CARDS, SO WE THOUGHT WE'D BRING SOME OF THE PLANET'S MOST SPECTACULAR NATURAL PLACES TO YOU**

WORDS: DR HELEN PILCHER

GERALD MACAU/SOLENT NEWS/SHUTTERSTOCK

↑

# A SLICE OF RAINBOW CAKE

**ZHANGYE NATIONAL GEOPARK, CHINA**

These impressive formations are sometimes called the 'Rainbow Mountains'. When the strata (bands of sediment) were formed, around 100 million years ago, they were laid down horizontally, like the layers of a cake. The colours came as iron-rich minerals permeated the sediments and interacted with the water and oxygen there. Iron reacting with oxygen forms iron oxides, which can be bright red, green or grey, depending on the amount of oxygen present. This, in turn, would have been influenced by the climate. "Red layers probably reflect a drier, more desert-like environment when the rocks were being formed, whilst paler layers suggest wetter conditions," says geologist Prof Jan Zalasiewicz at the University of Leicester. As the sediments were buried and slowly turned into rock, groundwater may have added a further imprint of chemistry and colour. The layers acquired their characteristic tilt when colliding tectonic plates crumpled and forced the rocks upwards.

SHUTTERSTOCK, ALAMY

↑

# ICED GEM

**VATNAJÖKULL ICE CAVES, ICELAND**

Stepping into the Vatnajökull ice caves is like setting foot in another world. Enormous passages carved into the heart of Iceland's largest glacier cast a starry blue light so surreal it wouldn't look out of place in a van Gogh painting. The caves are formed because of the seasonal freeze/melt cycles. In spring and summer, meltwater floods down into the glacier, creating a network of underground rivers that erode the ice. In winter, when the floods dry up and the rivers recede, the caves become exposed. The walls of the caves are made of ice that is thousands of years old. Compressed by the weight of the glacier, the ice is dense and lacking in air bubbles. This results in big ice crystals, which absorb the longer wavelengths of visible light – red, orange, yellow and green. The remaining light that we see is composed of shorter wavelengths of blue and violet, giving the ice caves their characteristic sapphire-coloured hue.

GETTY IMAGES, ALAMY

## NIGHT LIGHTS

**OKAYAMA PREFECTURE, JAPAN**

Their lives may be brief, but they are dazzling. Although adult fireflies live for just a few short weeks, they light up the undergrowth with their bioluminescent backsides. In Japan, the show begins around early June, as the insects emerge from their pupae and start looking for love. They attract mates by emitting carefully choreographed bursts of light from specialised organs in their abdomen. Many species have their own unique flash pattern, which helps them to identify members of their own kind, and studies have shown that females often prefer males who flash more frequently and intensely. Don't, however, be fooled by their name. 'Fire-like' they may be, but 'fly' they are not. Fireflies are actually beetles belonging to the Lampyridae insect family.

## RIVER RUNS RED

**CAÑO CRISTALES, COLOMBIA**

The Caño Cristales river tumbles through the mountainous Serranía de la Macarena National Park in Colombia. In June, when the rains come and the river level rises, the clear waters become awash with colour, thanks to an endemic herb called *Rhyncholacis clavigera*. Clinging to the bedrock, the aquatic plant bursts into life and causes the river to turn scarlet. "Its colour is quite unique amongst the world's freshwater aquatic plants," says biologist Dr Carlos Lasso from Colombia's Humboldt Institute. "*Rhyncholacis clavigera* helps to structure the aquatic ecosystem by providing food and habitat for native species," he says. "Many species of invertebrates and fish depend on it, and mammals, such as the tapir, feed on it too."

GETTY IMAGES X2, DR JAMIE CRAGGS

↑

# BLOOMING HOT

**ANZA-BORREGO DESERT STATE PARK, CALIFORNIA, US**

Every couple of years, when the conditions are just right, the Californian desert puts on a wildflower display so spectacular that it leaves many onlookers speechless. "Most people are shocked because they're not expecting to see such beauty in such an arid landscape," says botanist Prof Mark Chase from Kew Royal Botanic Gardens. The environment is harsh, so most of the time, many wildflowers such as these pink desert sand-verbenas and yellow California evening primroses sit it out underground as seeds. Then, if there's a good amount of rain in the winter months, they explode into life the following spring, flowering, producing seeds and dying within a few short weeks. "Competition to attract pollinators is intense, so the plants have evolved to produce a lot of nectar and also to be very colourful and showy," says Chase.

→

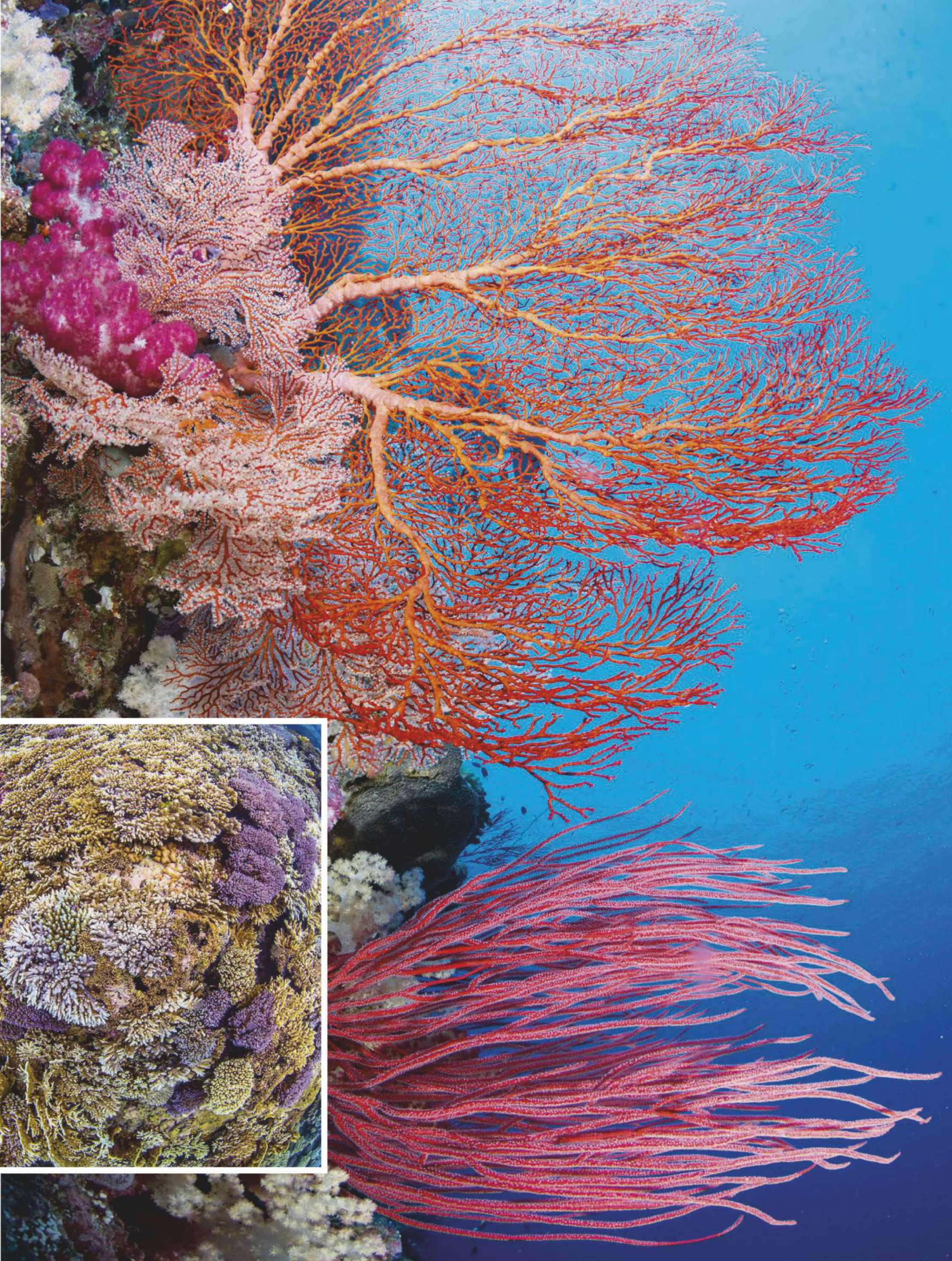
# CORAL KALEIDOSCOPE

**PALAU & GUAM, WESTERN PACIFIC OCEAN**

Corals come in many vibrant shades. Some, like these soft-bodied corals in Palau (main image), come in Barbie pinks and neon oranges, while others, like these hard-bodied corals in Guam (inset image), display a more muted range of tones. Soft-bodied corals produce bright pigments which help provide protection from the Sun by reflecting sunlight. Hard-bodied corals, which are the ones that build reefs, owe most of their colour to the symbiotic algae living inside their cells. The algae provide the corals with nutrients and sunscreen, and the corals provide the algae with a safe place to live. The hard-bodied corals in this photo are healthy. But when water temperatures increase, the algae can be ejected, making the coral look white, or 'bleached'. Sometimes, however, ghostly hints of colour remain, says coral expert Dr Jamie Craggs at London's Horniman Museum. "That's the coral's natural pigment." SF

by **DR HELEN PILCHER** *(@HelenPilcher1)*

*Helen is a science writer. Her latest book* Life Changing: How Humans Are Altering Life On Earth *is out now (£16.99, Bloomsbury Sigma).*



# HOW DOGS CAN HELP US LIVE LONGER, HEALTHIER LIVES

## Our best friends' biology could unlock the secret to ageing well

by **ANDY RIDGWAY**

GETTY IMAGES

How would you react if someone told you that just taking some pills or having an injection could add 20 years to your life? Not only that, but those extra two decades would be healthy years. You would probably not believe them.

But for the past few decades, research has been taking place to understand exactly what happens when we age and what drives those changes. While the effects of ageing have always been abundantly clear, what's going on inside our bodies that makes those things happen has not.

Now, a new wave of this research into the science of ageing is taking place not in humans, but in our closest companions – dogs. While studying dogs may not seem the most obvious way to try and understand human ageing, our furry friends can actually give us insights into our biology that we cannot.

Dogs share our homes, so they are exposed to many of the same factors that influence how well we age. But they also age much faster than we do – providing scientists with a accelerated view of the processes. There's another important factor too. When you put the fur and four legs to one side, dogs and humans are much *more* alike than you might think.

It's why several large research projects have sprung up in the past few years that are seeking to understand how dogs age – not only to help them, but us too. One of the most recent additions to the pack is the Dog Aging Project in ➔

the US, which since its launch in November 2019 has recruited 80,000 canine participants. The scientists involved with it will soon be picking over the lifestyles and health of these dogs to see what they can uncover.

Some of these pooches will also be taking part in the trial of a drug that is currently given to organ transplant patients. In tests in the lab, on everything from mice to flies, the drug has revealed its ability to extend life. But research in the lab is one thing. If it works on dogs that live in our homes, it would be the best evidence yet that it could do the same for us.

**BARKING UP THE WRONG TREE**

Thinking about medical treatments for ageing itself is a very different approach to how we usually think about our health. "What we have been doing for the past 200 years is trying to cure diseases, which is absolutely the wrong approach to increasing healthy longevity," says Prof Matt Kaeberlein, an expert in the biology of ageing at the University of Washington and a founder of the Dog Aging Project.

"Curing age-related diseases one at a time, a whack-a-mole approach, is not effective. If you were able to cure cancer, heart disease and kidney disease at the same time with a magic pill, a 50-year-old woman would get about a decade of extra life," says Kaeberlein, owner of Dobby the German Shepherd (9) and Chloe the Keeshond (14). "You continue to have other age-related diseases like Alzheimer's disease, liver disease and lung disease, so the effect on life expectancy is relatively small." It also means those additional years may not be healthy years.

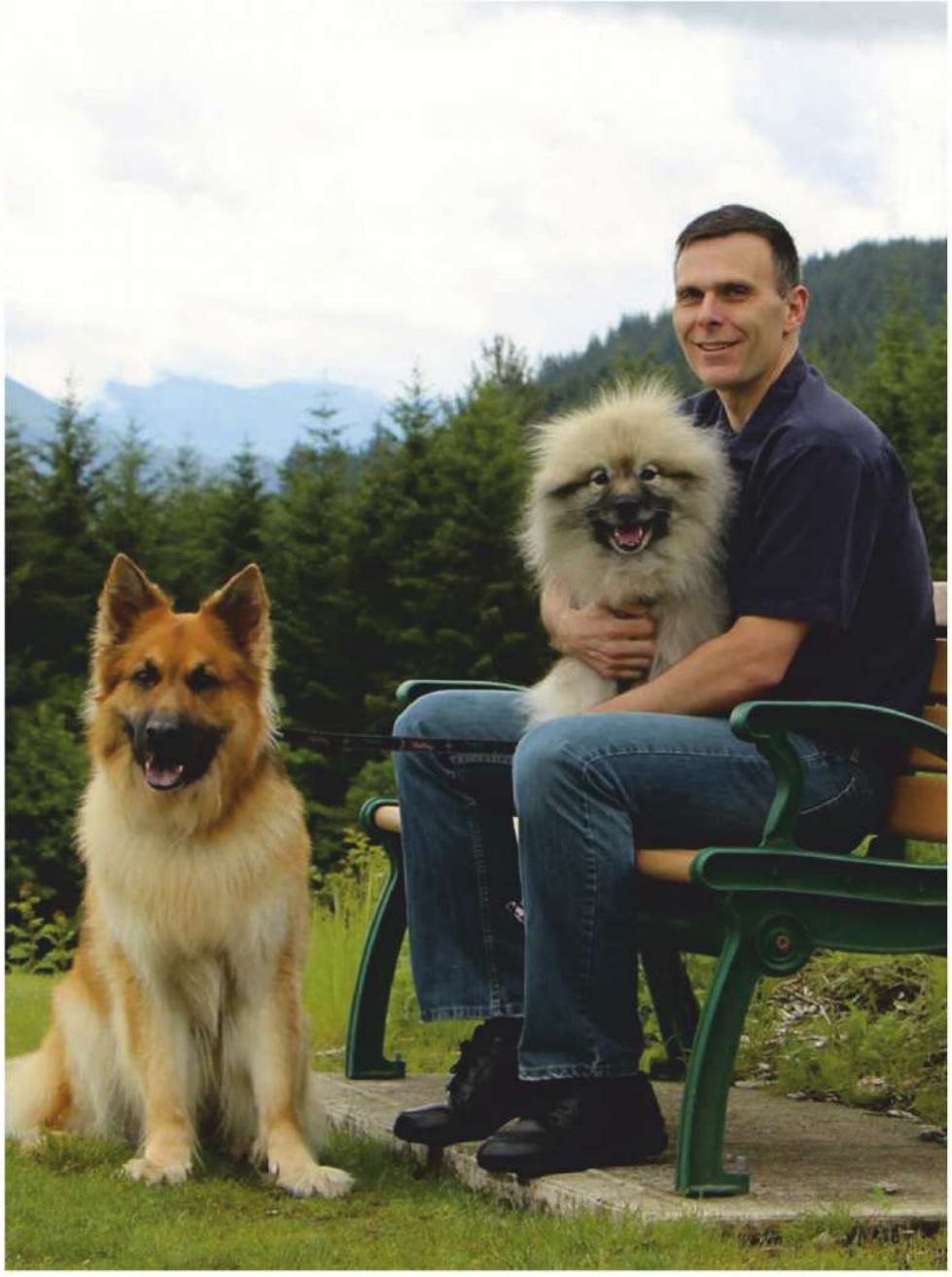
Much more effective, says Kaeberlein, is to slow down ageing itself. "If you target the molecular mechanisms of ageing, then we can expect more substantial effects on lifespan. But more importantly, those extra years will be in relatively good health," he says.

A central strand of the Dog Aging Project is to understand how our surroundings, such as the pollutants to which we are exposed, as well as our lifestyles, influence how long we live. Over the next few months, the dog owners in the US who are signed up to the project will be asked to complete a 200- to 300-question survey on the health and lifestyle of their pet – everything from what they eat, to what they drink and how much exercise they get. The researchers will also link this with publicly available data about the conditions the dogs are living in, such as the local air quality and the amount of green space near them.

"Dogs share our environment with us and in many ways they are more exposed to it than we are, so they are potentially sentinels for environmental factors shaping ageing," says Prof Daniel Promislow, an expert in ageing at the University of Washington and a co-founder of the project. "In normal times, we go to work every day and we might drink our water from a bottle instead of the tap and we don't tend to stick our noses in the dirt."

**"A VAST NUMBER OF REGIONS OF THE HUMAN GENOME HAVE BEEN FOUND TO BE SIMILAR TO THE DOG GENOME"**

**ABOVE** Dogs live in similar surroundings to us, so they can help scientists understand how our environments affect ageing



**CLOCKWISE FROM LEFT** Dog Aging Project co-founder Prof Daniel Promislow with Frisbee; co-founder Prof Matt Kaeberlein with Dobby and Chloe; co-founder Dr Kate Creevy with Poet and Sophie; project participant Megan Cloudman with Breeze; project team member Dr Audrey Ruple with Bitzer

GETTY IMAGES, THE DOG AGING PROJECT

There's also the fact that dogs age 7 to 10 times faster than humans. "Everything is speeded up in dogs, so if there is something in the environment that creates an increased risk of disease, maybe an endocrine disruptor or something, it might take 30 years to show up in a human, but it might show up in three or four years in a dog," says Promislow, owner of mixed-breed dog Frisbee (13).

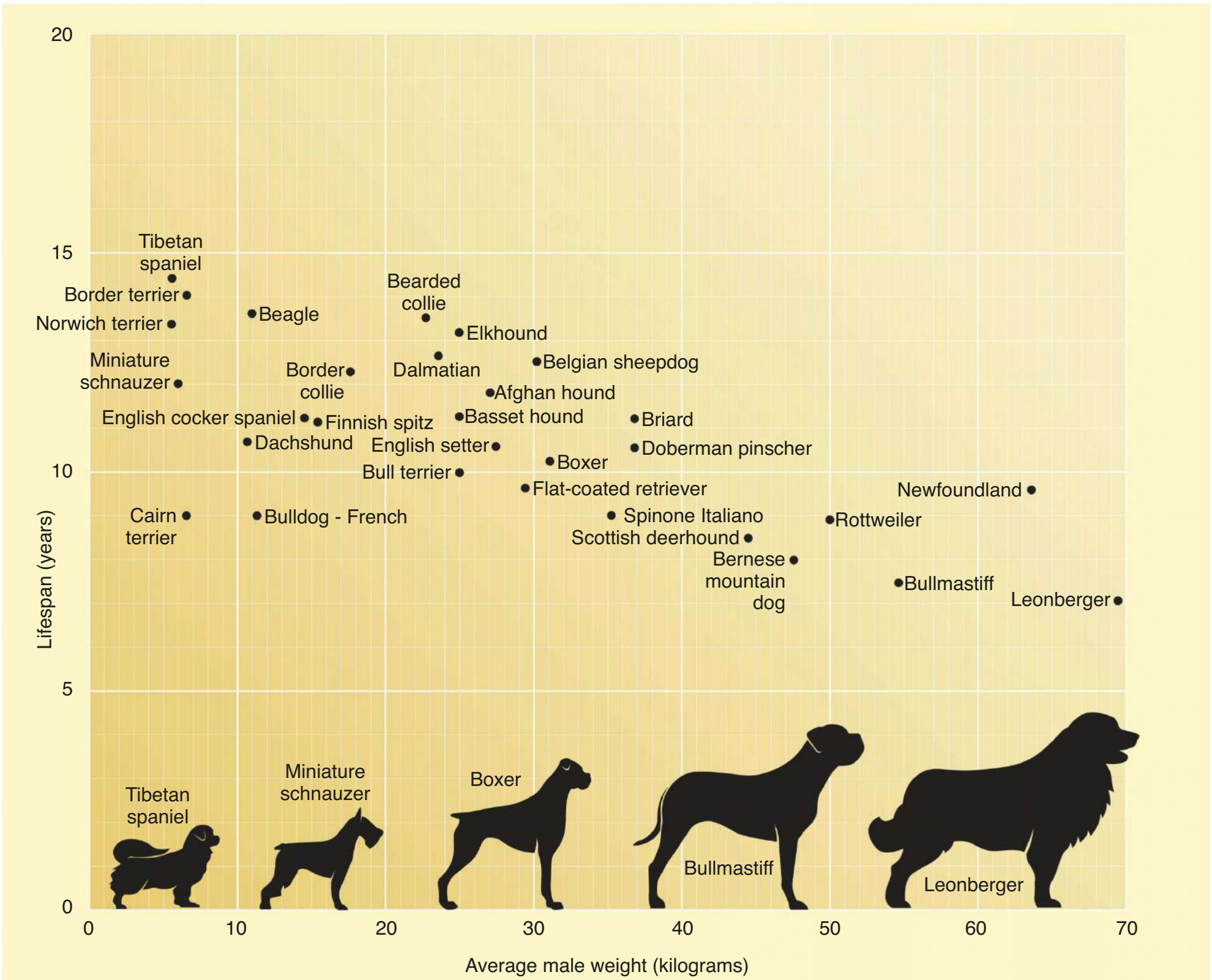
Dogs also get many of the same diseases as we do. "They get cancer, kidney disease and intestinal disease," says Promislow. The similarities don't end there. "When I give talks to people involved in human medicine, I give them a list of the drugs being used to treat anxiety in dogs and they are all the same drugs they are using with their human patients," says Prof Elinor Karlsson at University of Massachusetts Medical School.

Karlsson is founder and chief scientist of Darwin's Ark, another dog-ageing research project. As the owner of four cats, Darwin (16), Lacey (4), Hopper (3) and Beagle (3), she hopes to run a similar ageing research project with domestic cats and so provide further opportunities to find out what affects ageing most.

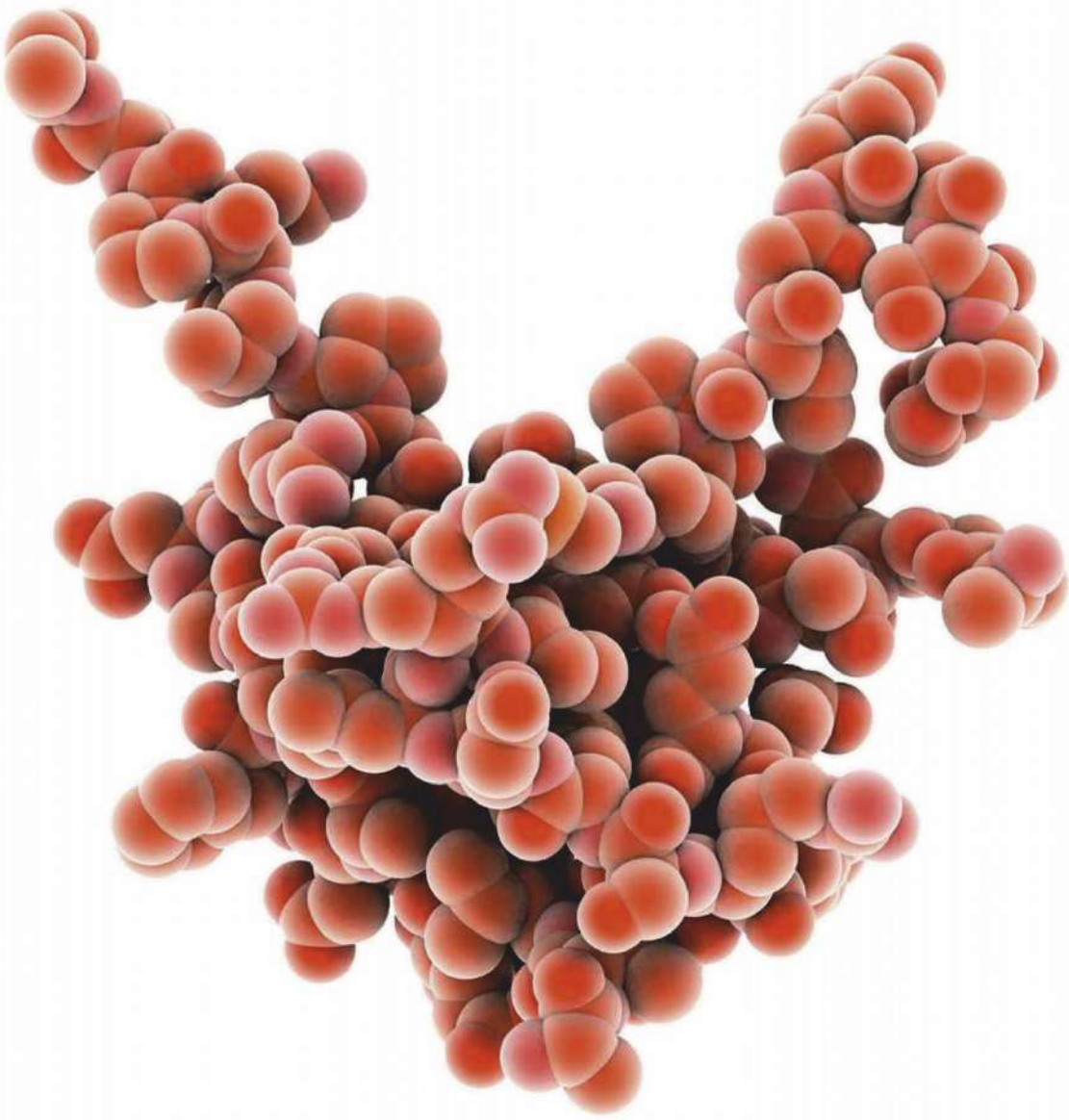
The similarities between human and dog get right down to the level of our

**RIGHT** Dog size is controlled in part by one gene, IGF1 (pictured) which seems to be linked with lifespan

**BELOW** Smaller dogs tend to live longer than larger dogs, and the Dog Aging Project is trying to find out why this is the case




GETTY IMAGES, SCIENCE PHOTO LIBRARY ILLUSTRATION: ACUTE GRAPHICS



DNA. A vast number of regions of the human genome have been found to be similar to the dog genome. That's important, because how long we live and how well we age is under the influence of our genes as well as our environments and our lifestyle. There are tantalising signs that dogs can provide some interesting insights here too.

Back in 2007, a genetic study of 143 dog breeds published in the journal *Science* showed that about 50 per cent of the variation in dog size is down to a single gene, called IGF1, that's also found in our cells. Small breeds, such as the Chihuahua and Pekingese, all have one particular version of the gene, whereas giant breeds, such as Great Danes, have one of two other versions. It came as quite a surprise that a characteristic so varied in dogs is controlled to such an extent by a single gene.

"The other thing that's interesting is that IGF1 has been associated with lifespan in the lab in mice and flies," says Promislow. It prompts an intriguing question. Could this gene be a reason why large dog breeds tend to be shorter lived than smaller ones? This is something of an oddity given that larger animals, such as elephants, tend to live longer than smaller ones, such as mice. It is a question the Dog Aging Project is looking to answer.

### WOLVES UP YOUR STREET

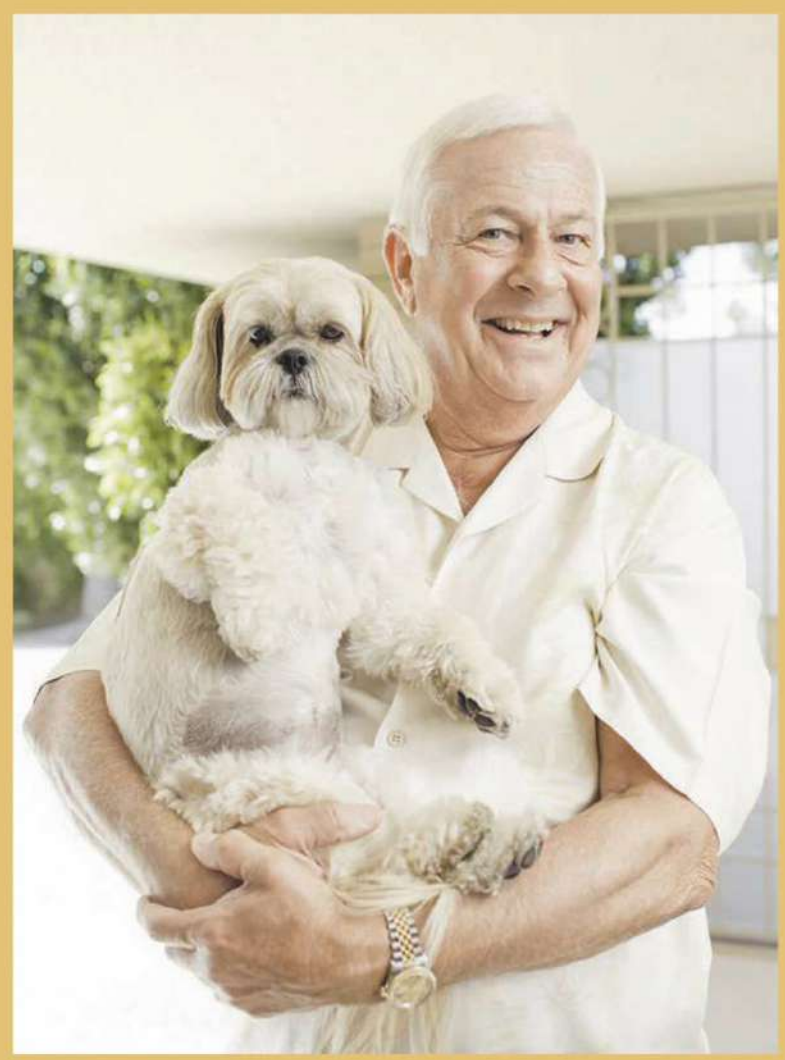
Domestic dogs, *Canis familiaris*, started evolving from the Eurasian grey wolf, *Canis lupus,* around 15,000 years ago, and it's our selective breeding of them that has made them the most diverse species of mammal on the planet. The Kennel Club in the UK recognises 218 breeds. All those differences provide a great opportunity to study ageing.

"Dogs are the most varied species of mammal in terms of size, coat colour and behaviour, but also the things we don't see – the diseases they die of and how long they live for," says Promislow. "So that ➤

## CAN OWNING A DOG EXTEND YOUR LIFE?

**Some of the best evidence that having a dog in your home can help you live longer comes from research published in 2019 by Canadian scientists who pooled together 10 studies that collectively involved over three million people. It showed that people with a pet dog were 24 per cent less likely to die over the course of the studies, which averaged 10 years, than those without a dog. This research didn't show exactly *how* owning a dog extends your life though. Just that statistically it does, or appears to at least. The researchers suggest a large part of a dog's life-lengthening effects may simply be that dog owners get more exercise, by virtue of all those 'walkies'. But the researchers say that interpreting the results is not straightforward. Part of the difference may simply be down to dog owners tending to be people who are fitter with healthier lifestyles.**

**There is evidence though that having a dog in our homes does reduce the likelihood that we'll get allergies. Over the past decade, several studies have looked at the prevalence of allergies in homes with and without pets. One of the most recent, published in 2019 by an international research team, showed that having a dog in the house cuts the risk of asthma in children – and having a cat reduced the risk of eczema.**



creates an enormous opportunity to understand the way in which genes and environment shape ageing."

The dogs within the Dog Aging Project fall into different groups depending on how they will be involved in the research. All of the 80,000 dogs whose owners fill out the health and life experience survey over the coming months will become part of a 'project pack' that will be followed for the rest of their lives to monitor how their health changes and at what age they die. These dogs live in the US, but the hope is to expand the project internationally. "People love dogs and we are working with dog owners," says Promislow. "In a great act of altruism they are sharing their data with us."

One group of 10,000 dogs in the project pack will also have their whole genomes sequenced, while the owners of a group of 1,000 will be handed kits to give to their vets to collect samples of hair, blood, poo and other things. This group will help researchers understand more about the dog microbiome (which again shows a striking similarity with ours) to explore the role it plays in ageing.

Then there's trial of the potentially life-extending drug, rapamycin, that will involve 500 dogs. The dogs in the rapamycin trial will have regular check-ups at veterinary teaching hospitals across the US to see what effect it has on them. "I'm a dog person, I've had dogs all my life so I wanted to try something that we were confident could be tested safely," says Kaeberlein. "Organ transplant patients take rapamycin for decades without significant problems."

Researchers already have some insights into how rapamycin slows ageing. It does it by reducing levels of a protein in the body called mTOR. Reduced mTOR levels increases the rate of autophagy, the process in cells that breaks down damaged molecules and acts as a recycling system. "There is pretty good evidence that this turning up of autophagy can help break down some of the damage that has occurred in ageing at a molecular level and recycle some of the building blocks into new molecules," says Kaeberlein.

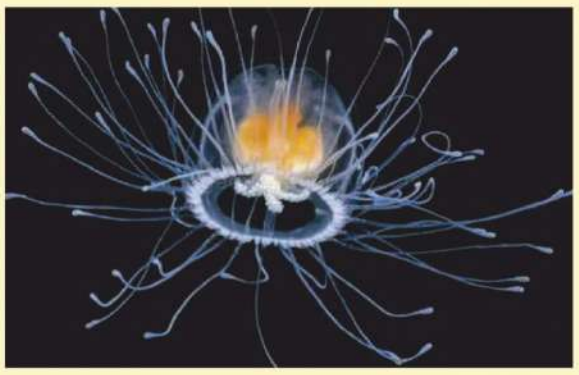
These damaged molecules that are broken down may include the misfolded and clumped together proteins that have been linked with Alzheimer's disease. Rapamycin may also help recycle mitochondria, which are the powerhouses inside our cells. "We know mitochondria are damaged with

DOUG PERRINE/NATUREPL.COM, ALVARO E MIGOTTO/BLUE PLANET ARCHIVE/IMAGEQUESTMARINE.COM

## LESSONS IN LONGEVITY

### STEADYGOING SHARK

The Greenland shark (*Somniosus microcephalus*) may live more than 400 years, making it the longest-lived vertebrate. The best evidence for their longevity came from a study published in *Science* in 2016, when the eye lens of one of these sharks was radiocarbon-dated at 392 years old, plus or minus 120 years. The predator is providing some useful insights into ageing. It thought its chilly habitat may switch on anti-ageing genes that get rid of DNA-damaging molecules and help fight off infections.



### THE IMMORTAL JELLYFISH

The jellyfish *Turritopsis dohrnii* seemingly has the power of immortality. A bit like Doctor Who, it can regenerate to a younger state. It achieves this feat by switching its cells from their adult state to an earlier 'polyp' form. While transforming our cells back from their adult form to an embryonic-like state would not be advisable, changing aspects of our cells to make them younger may still be an option. If we tweak the way our DNA is packaged, it may be a way to dial back the ageing clock .

### LONG-LIVED LOBSTER

Although not immortal, lobsters can live a long time – male European lobsters live an average of 31 years, and females live 54 years. They grow old gracefully too, not showing some of the typical signs of ageing. Lobsters' longevity has been put down to the high levels of an enzyme, telomerase, in their bodies. Telomerase regenerates telomeres – the protective caps at the end of chromosomes. Humans have telomerase too, and researchers are seeing whether it could offer a way to hold back the hands of time.

age and there's an autophagy process called mitophagy which can break down damaged mitochondria and recycle them into new building blocks."

The rapamycin trial isn't the only test of a potentially life-lengthening treatment in dogs. A US business Rejuvenate Bio, founded by high-profile Harvard Medical School geneticist Prof George Church among others, has started pilot testing a life-enhancing gene therapy in dogs. The trial involves injecting American Cavalier King Charles spaniels with a harmless virus that carries genes for proteins found to dial back ageing, by improving things like heart health and kidney function. If all goes well, the trial will be expanded to other dog breeds and then, possibly, human trials can start.

But there's still the question of our perceptions of research into life extension. Prof David Sinclair, an expert in ageing at Harvard Medical School and author of *Lifespan: Why We Age And Why We Don't Have To* thinks the dog research may help change how we think about ageing.

"Most of us dog owners would say our dogs don't live long enough, although most of us would say humans live a long time," says Sinclair, owner of a Labrador named Leuka (6), and a crossbreed called Charlie (13). "But it's only relative. If two-thirds of humanity lived for 150 years, those who didn't live beyond 80 would be pitied. I think eventually society will change and realise 80 years is not very long in the grand scheme of the Universe."

Kaeberlein also thinks the research in dogs will convince people that ageing is now under our control. "This is not science fiction, it's biology," says Kaeberlein. "People love their dogs and if we can help people's dogs live longer by slowing ageing, it might change the way people think about the biology of ageing and recognise it is possible in humans too." **SF**

**"IF WE CAN HELP DOGS LIVE LONGER BY SLOWING AGEING, IT MIGHT CHANGE THE WAY PEOPLE THINK ABOUT THE BIOLOGY OF AGEING"**

ALAMY, GETTY IMAGES

by **ANDY RIDGWAY**
*(@AndyRidgway1)*
*Andy is a freelance science writer and the owner of a Labrador, Lunar (2).*

BBC

HistoryExtra COLLECTION

FROM THE MAKERS OF *BBC HISTORY MAGAZINE*

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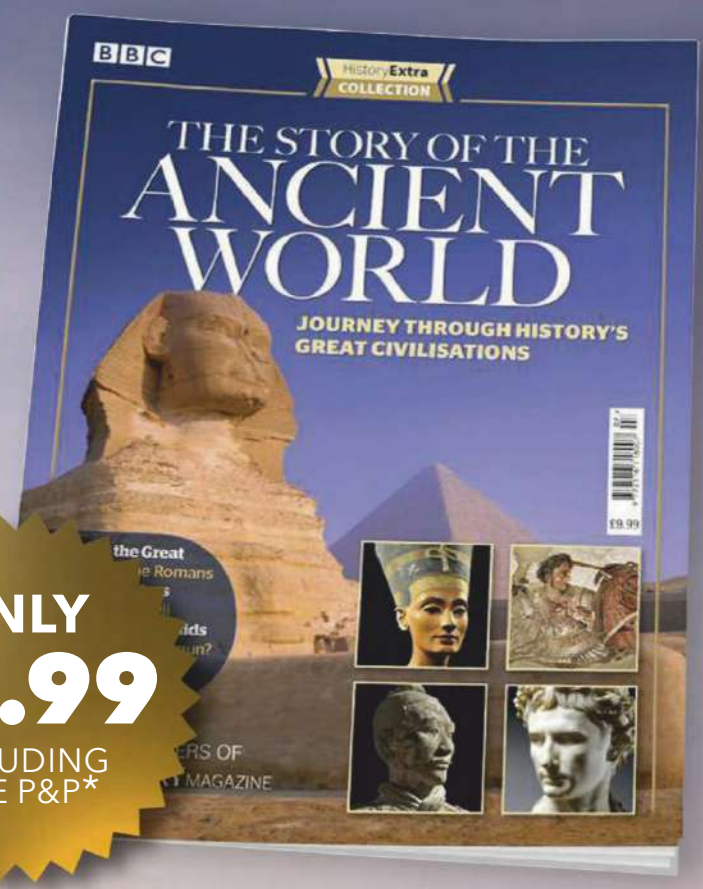


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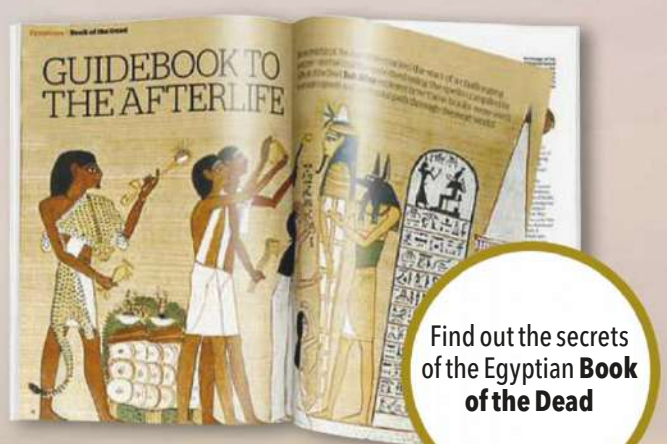


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COMMENT

# SHOULD I TAKE ZINC TABLETS?

Many people are taking supplements to try and keep COVID-19 at bay. Do they work?

The best way to protect yourself from COVID-19 is to carry out social distancing and regularly wash your hands. But as shops and workplaces reopen, what about bolstering your body by taking other remedies – such as zinc supplements – which have been vaunted as a way to help prevent COVID-19?

Your body contains around two to three grams of zinc. There are more than 300 enzymes whose activity is linked to zinc, which helps explain why your body needs it for a wide range of roles, including wound healing, protein synthesis and ensuring a fully functioning immune system.

So you certainly need zinc to stay healthy, but is there any benefit from taking supplements? The best evidence comes from intervention studies, where scientists have given zinc lozenges to people who are exposed to the common cold. In a meta-analysis published in 2017 in the journal *JRSM OPEN*, they looked at people taking zinc lozenges in the form of zinc acetate or zinc gluconate and found that taking zinc had an effect. In three trials where people were given zinc acetate, or a placebo, the zinc acetate shortened the duration of a cold by 40 per cent. Similarly, in four trials where people were given zinc gluconate, or a placebo, those taking the zinc gluconate found it reduced the duration of a cold by 28 per cent.

**“The zinc acetate shortened the duration of a cold by 40 per cent”**

The team behind the meta-analysis concluded that “common cold patients may be encouraged to try zinc lozenges for treating their cold”.

So why did the zinc supplements make a difference? We know that zinc is important for your innate immune system, the part of your immune system that is constantly on the alert for infections and is first to act. Zinc helps white cells like monocytes bind to infected cells and either phagocytose them (‘eat’ them) or poison them. If you are zinc-deficient there is also a decrease in the activity of white cells called natural killer cells.

The people who seem to get the most benefit from taking zinc are the over-60s, as zinc deficiency is common in older age groups. Taking zinc supplements has been shown to suppresses the formation of pro-inflammatory cytokines, the sort that can lead to a ‘cytokine storm’. This is when the immune system overreacts and attacks healthy cells – this seems to be what causes death in many older people who get COVID-19.

You get zinc from eating shellfish, fish and meat. You also find it in nuts, seeds and legumes, but in a less absorbable form.

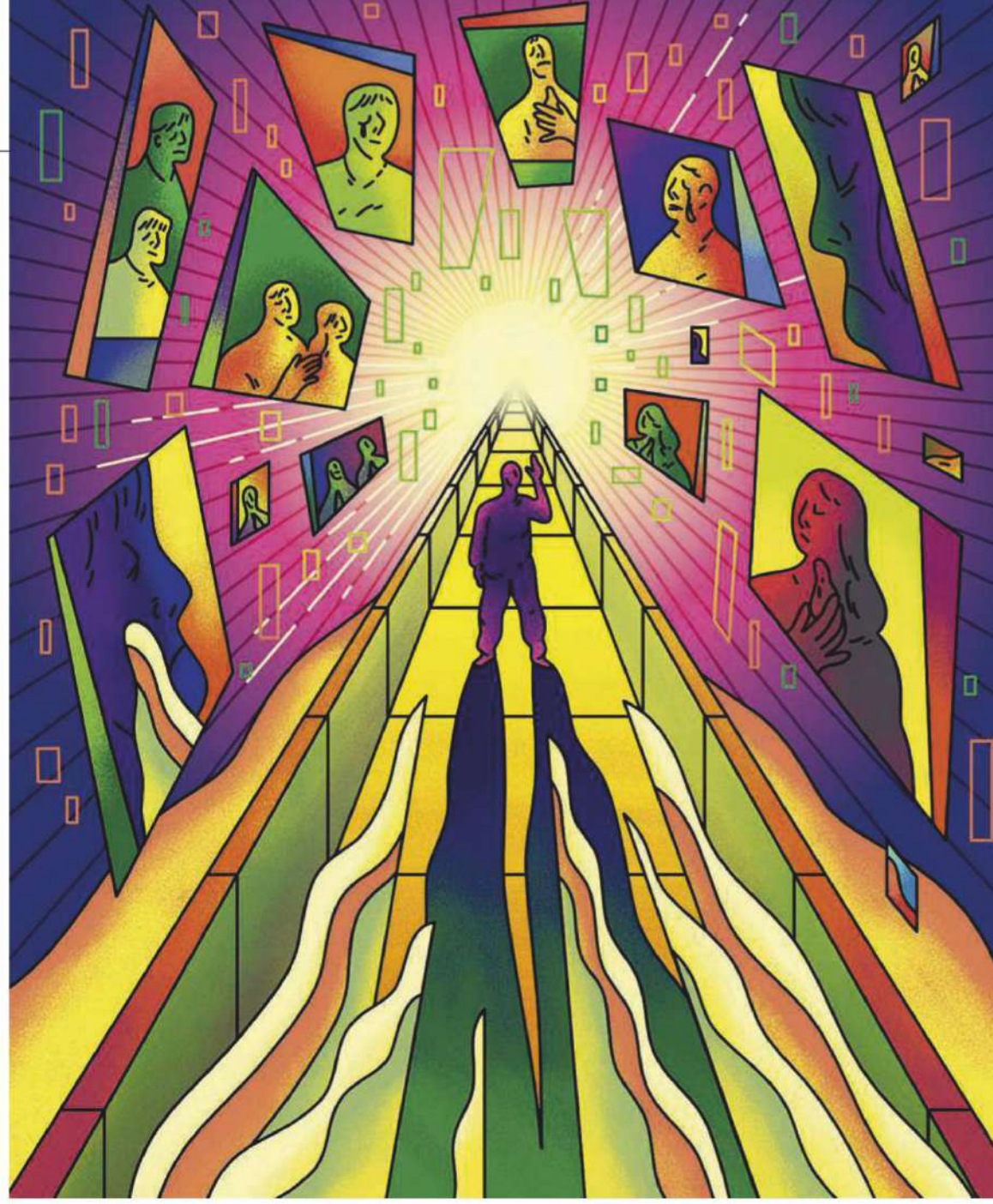
So should I be taking zinc? I’m sure I get enough in my diet, and there is no real evidence it will help with COVID-19, but if I get symptoms I probably will start taking zinc supplements, just in case. But don’t take more than 40mg per day and consult your doctor if you are taking other medication. **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I’m A Doctor.* His latest book is *Fast Asleep* (£9.99, Short Books).


BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: JASON RAISH



COMMENT

# MAKING SENSE OF DEATH

We can no longer celebrate lives through large funerals and wakes, but could technology offer a way to help us negotiate our grief?

When my Dad died at the very beginning of 2016, it started a concentrated time of many losses. It was an artefact of age – in the following three years, I lost all of those who were left in his generation and above. By the end of 2019, after a few clear months without a visit to a funeral home, I stopped anticipating the news of a loved one facing the philosophical fullstop, and relaxed. I had achieved the final stage of grief. I started to make sense of it.

But then came COVID-19 and the incomprehensible loss of life that we have been surrounded by for the last few months, and everything has been upended again. While I am mercifully spared – so far – from its mortal bite, here in New York City I am literally surrounded by the realities of the mass of casualty.

I understand how isolating death is during normal times. What I don't know is how isolating death is at a time of so much loss. Apart from the greatest cruelty of physical isolation, I wonder whether the personal experience of those who have survived is transformed because their worst day is eclipsed by the 'number theatre' of daily statistics.

I recently spoke with Valerie Cole, leader of the US Red Cross Integrated Condolence Care Program. Her team of professional mental health volunteers are always on the scene after a disaster. She says there is probably some comfort in knowing you're not alone. We make sense of an upside-down world by coming together to figure out how to interpret it. But how do we begin to process when the coming together is physically distanced?

**"Our job is to make sure we are there, checking in, sharing stories, sitting in virtual silence and tears"**

The internet has gifted us the video conference. So much of grief is visual, and if we can't be there in the room, we can at least see the room through a camera. We can sit with someone in silence. David Kessler from **grief.com** has watched the transformation in online rites over the last few months, from clergy with terrible sound quality talking to an empty room, to Zoom funerals, where they can speak directly to the bereaved, who can also see everyone else.

David hosts a popular online support group to give the bereaved a place to reality check their feelings. Valerie's team now communicates from a distance, guiding people through the disorientation of mass casualty loss, and making sure their needs are met so they can begin to mourn. While they can't give someone a hug, they can leave the person with a next step, to negotiate the path through uncertainty.

Our job, as non-professionals supporting someone through a loss, is to make sure we are there in two weeks, a month, three months from now, checking in, sharing stories, sitting in virtual silence and tears. Over the next year, we will test technology in ways it was never meant to be used. But with the hacks we are using to overcome the most significant lockdown obstacle, we will come to make sense of what is important in life, and how we can continue to live despite death. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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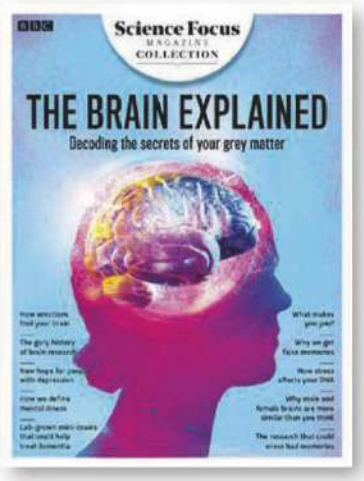


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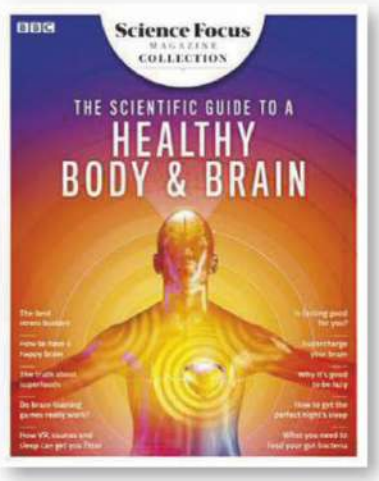


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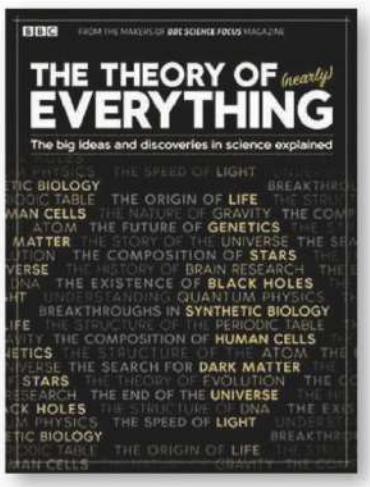


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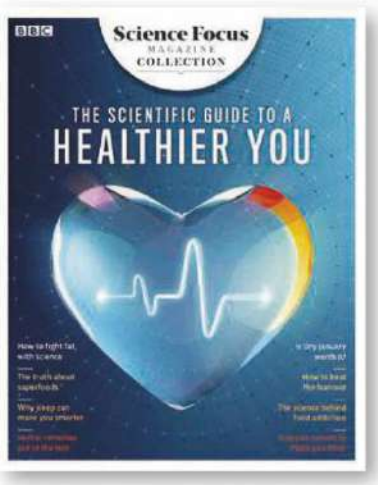


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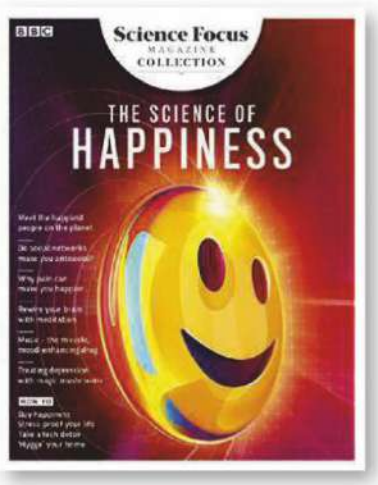


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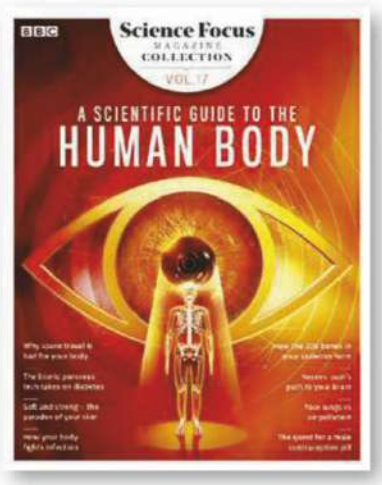


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# SWEET DREAMS ARE MADE OF CHEESE

by DR STUART FARRIMOND

**When milk and microbes come together, there's no doubt something wonderful happens. We asked a food scientist how a choreography of chemistry, biology and psychology make cheese the ultimate food**

Who would have thought that a congealed lump of curdled milk could be so delicious? For 7,000 years, cheese has titillated the taste buds of humanity. In almost every corner of the world, animal milk has been used to create the stuff, culminating in over 1,700 distinct varieties today: creamy Brie; buttery Gouda; crumbly Parmesan; stringy mozzarella; sharp Cheddar; holey Swiss; mild paneer; smoky Bavarian Emmentaler… the list goes on and on. The staggering variety of cheeses is testimony to the creativity of cheesemakers throughout the ages, but their ingenuity plays second fiddle to the real stars of the show: the microbes. The several-hundred-strong ensemble cast of bacteria, fungi and yeasts bring life to a bland, salty lump of off-white curd. By digesting, or 'fermenting', the fats, proteins and milk sugars, they spew forth a complex selection of flavourful – sometimes smelly – molecules. Never has second-hand food tasted so good! But what is it that makes cheese so devilishly moreish?

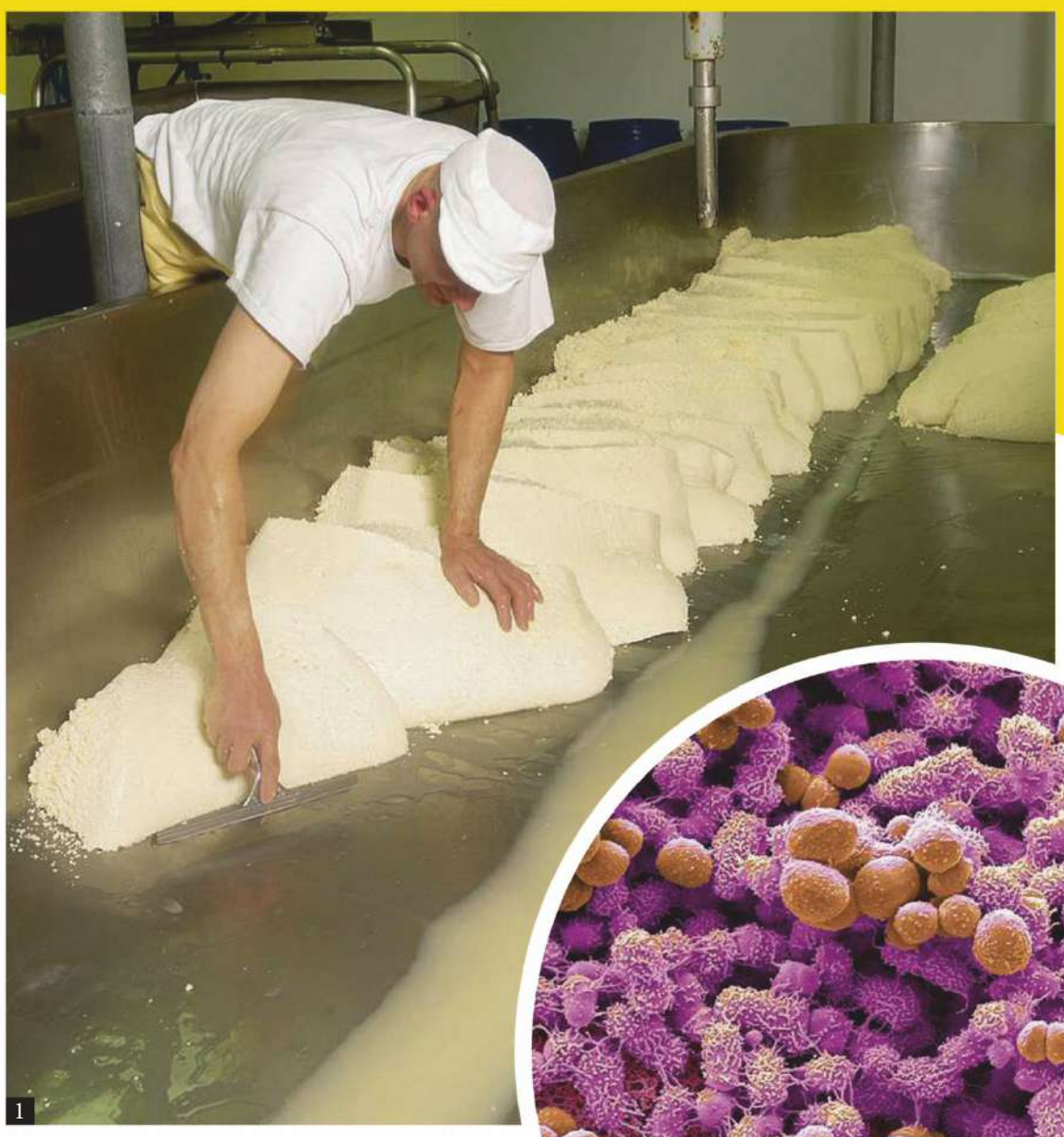
## THE MILKY WAY

All cheeses start their lives as milk. Most animal milks can be used, including cow, buffalo, goat, sheep and even camel. The milk is first warmed to a temperature perfect for milk-loving microbes to flourish. Next, acid or rennet is added, possibly alongside some 'starter' bacteria, This causes the milk proteins and fats to coagulate together into ugly white clumps, 'curdling' the milk. These fat-laden 'curds' then float to the surface of the milky liquid, the 'whey'. The curds can then be drained, removed and chopped into chunks, according to the type of cheese being made – walnut-sized blobs for soft cheeses, and small grains for hard cheeses.

The curds are scooped into moulds, but the initial 'starter' bacteria, which give cheese its lactic acid tang, die off over several weeks to make room for a microbe superhighway of new flavour generators. Plenty of salt is added to the mix to stop any rancid milk-loving microbes from spoiling the brew.

In the months that follow, a second wave of hungry 'ripening' microorganisms gradually start munching into the cheese to create the potent flavours and aromas. These ripening microbes chew off portions of the proteins,

ILLUSTRATION: ADAM GALE



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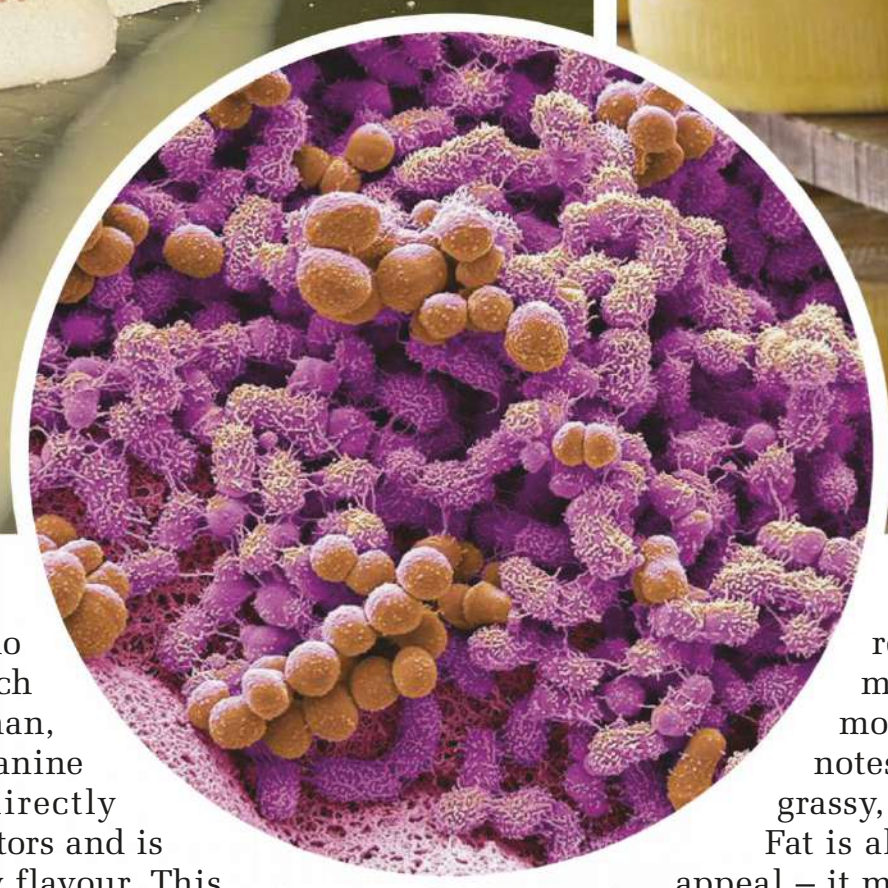

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breaking them into their amino acid component parts – many of which have their own flavour. Tryptophan, for example, has a bitter taste. Alanine tastes sweet, while glutamate directly stimulates the umami taste receptors and is responsible for a cheese's savoury flavour. This umami kick is commonly found in fermented and high-protein foods, as well as seaweed and tomatoes. When glutamate is added to foods (typically as the unfairly maligned MSG, or monosodium glutamate), it gives it a 'just-one-more-bite' addictive quality.

Particularly voracious bacteria and fungi will break down amino acids even further to produce truly whiffy by-products that are identical to those found in nature's pongiest places. Chemicals produced by cheese microbes include putrescine, which is responsible for the smell of putrid meat; trimethylamine, which gives rotten fish its room-clearing odour; and ammonia, which carries the fragrance of toilet cleaner.

The journey doesn't stop there, thankfully, and over months of further ripening, smelly fragments can interact and recombine in new ways to produce more appetising flavour-carrying molecules. These substances convey notes that can be nutty, spicy, woody, grassy, or even have hints of burnt oats.

Fat is also chief among cheese's moreish appeal – it makes pretty much anything taste good. With a few provisos, the more fat a food contains, the tastier it becomes. We crave this calorie-packed nutrient due to our evolutionary programming, as it will give us fuel to survive the next famine. Fat's irresistible allure is partly due to fat-sensitive receptors on the tongue, which is why low-fat alternatives never quite have the same appeal.

Any food's aroma- and flavour-carrying substances are known collectively as 'flavour compounds'. They typically dissolve well in oils, fats and alcohol, but poorly in water. Fat-rich foods will therefore have their flavour compounds infused and well spread throughout, meaning that each mouthful will smother the tongue with a flavour that lingers, while also giving ample time for these easily vaporised compounds to

**1** Separating the curds from the whey during cheese-making

**2** *Brevibacterium* is found on our feet, but also gives certain stinky cheeses their characteristic aroma

**3** As cheese ripens, microbes get to work on the proteins and fats, creating a wide range of yummy aromas and flavours in the process

GETTY IMAGES X2, SCIENCE PHOTO LIBRARY

**"IT'S NOT OUT OF THE QUESTION THAT WE HAVE CHEESE THAT SMELLS LIKE SOCKS BECAUSE AT SOME POINT IN THE DIM AND DISTANT PAST, SOMEONE'S FEET GOT A BIT TOO CLOSE TO THE CURDS"**

waft up the back of the throat into the nose as aromas where our nasal receptors interpret them as a 'taste' that comes from the tongue.

It's not just proteins that microorganisms munch on. Some microorganisms are also fat-digesters, such as the *Penicillium* moulds found in blue cheese. They break down fats into small molecules, some of which have a peppery taste and carry sheep/goat-milk aromas, while others give it an off-putting stink. One of these substances, known as mushroom alcohol, or octenol, has a 'mouldy' smell that is also found in breath and sweat. Mushroom alcohol also attracts biting insects, so keep your cheese covered and your skin clean on a hot day!

The real humdinger stinky cheeses, such as Munster and Limburger, emit vapours that contain molecules identical to those given off from old socks, and also harbour the same bacteria. Called *Brevibacterium*, this is a so-called 'smear' bacteria that can grow on the moist outer surface of cheese, nibbling away and releasing chemicals such as butyric acid, which is responsible for the repulsive smell of vomit, along with methanethiol, which smells putrid. *Brevibacterium* also flourishes in the damp recesses between warm toes and it's not out of the question that the reason we have cheese that smells like socks in the first place is because at some point in the dim and distant past, someone's feet got a bit too close to the curds.

## WHAT A STINK

Interestingly, we are all born with a natural aversion to such putrid smells, yet over time we learn to adore these intuitively unpleasant aromas. Furthermore, tiny traces of repulsive smells and flavours are sensed as pleasant, for reasons that no one really understands. Skatole, for example, gives poo its unmistakable whiff, yet in minute amounts it smells floral and perfumers use it in the stuff we splash on our necks. Humans seem to have a touch of gastronomic masochism, getting a thrill when nastiness accompanies our pleasures: bitterness – a warning sign for poison – is one of coffee's qualities, while tingling chilli heat is an essential component of curry.

These sensations also explain why the cheeseboard is so irresistible, even after a gut-busting meal. Our 'dessert stomach' is due to 'sensory specific satiety' – our food-obsessed minds crave novelty. When we have a new flavour offered, the desire to try something novel shortcuts our satiety and encourages us to tuck in.

It's testament to this moreishness that there have been some scientific-sounding claims bandied about that cheese is as 'addictive as cocaine' because it contains opium-like chemicals called casomorphin peptides – small bits of broken-down curd protein that happen to bear chemical similarities to the poppy-derived narcotic. If casomorphins made it into the brain after a cheese feast, then they could latch onto opioid receptors, numbing pain and giving a euphoric boost, much like morphine. However, if you plan on using cheese's mind-altering powers to excuse your Wensleydale obsession, then you are clutching at (cheese) straws: casomorphin also happens to be in milk and other dairy products, and compared to many morphine-like substances, any effects due to casomorphin are pretty tame. It turns out you are 'addicted' to cheese, just because it tastes so good. **SF**

by **DR STUART FARRIMOND**

*Stuart is a food science tutor at the University of Cambridge. His book,* The Science Of Cooking *(£20, Dorling Kindersley), is out now.*

INTERVIEW

# DOING IT FOR THE THRILL

We say that our feelings can be like a rollercoaster – and, as it turns out, the psychology of our emotions has influenced rollercoaster design from the beginning. Thrill engineer **Prof Brendan Walker** spoke to **Amy Barrett** about fairground rides, adrenaline and adventure, and why we seek out the seemingly scary...

**WHAT DOES A 'THRILL ENGINEER' DO?**

I came up with the term because I really like the idea of combining the objective practice of engineering, creating things with rules, with the subjective elements of human emotions. So, being a thrill engineer means I craft extreme, human emotional experiences, using design principles.

**WHAT PSYCHOLOGICAL LEVERS ARE YOU TRYING TO PULL WHEN YOU DESIGN A ROLLERCOASTER?**

If I put you on a rollercoaster and blindfolded you, your body's levels of arousal would pretty precisely track the changes in acceleration forces felt around the ride. Rollercoasters are successful because they really grab hold of that element of arousal and, because it's so tightly interlinked with physical sensations that we get from the world, we can almost force an emotional experience by the very shape of the rollercoaster.

**WHAT EMOTIONS DO WE GO THROUGH ON A RIDE?**

We have 43 different muscle groups in the face, and any combination can express different emotions that we're feeling.

I was interested in using the techniques that computers use to detect human expressions, to understand people's emotions on rides. Dr James Condron, from Massachusetts Institute of Technology, created a galvanic skin-response monitoring device, and worked with me on a project. We put people on fairground rides and used the technology to fire a camera when the device measured high levels of arousal. The 10 portraits from that project absolutely set in stone the range of emotions experienced across different ride types.

On a ride, people's emotions are constantly in flux – between extreme excitement, delight, joy, happiness all the way through to terror, horror, sometimes boredom as well. But the critical thing about thrill is that thrill isn't an emotion itself. It is the *change* in emotions.

**THERE'S A FINE LINE BETWEEN 'FUN' FEAR, AND BELIEVING YOU'RE REALLY UNDER THREAT...**

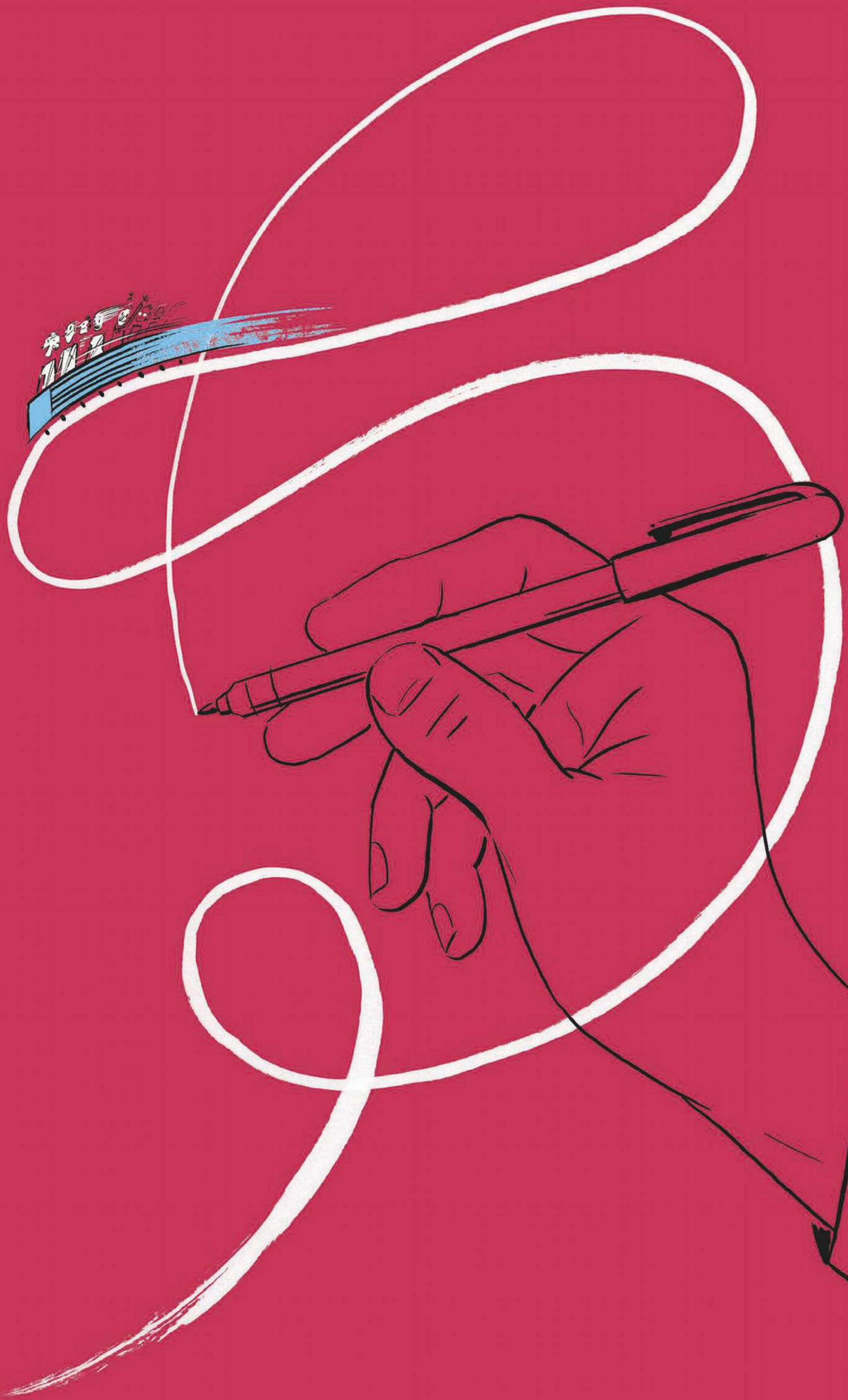
Absolutely. If I were to do an experiment through a university's psychology department, if I said that I was going to make people believe that they're really in danger... I would be in ethics committees for years.

Yet in entertainment, there's this sort of tacit understanding, a kind of unspoken contract between people who go seeking entertainment and those who provide it. The people going into amusement parks are saying, "I want to be challenged. I want to be taken to the edge, but I trust as part of this agreement, you are agreeing to ultimately keep me safe."

**WHY ARE SOME PEOPLE MORE SENSATION-SEEKING THAN OTHERS?**

You can look at the personality traits of people who tend to go to theme parks and on rollercoasters. In fact, I usually quote Marvin ➔

ILLUSTRATION: ADAM GALE



Zuckerman, a professor at the University of Delaware. I think of him as the grandfather of thrill-seeking.

He classified four different dimensions to sensation-seeking. One is thrill- and adventure-seeking, which is very much to do with rollercoasters and that kind of high adrenaline experience. Another one is experience-seeking – people who like unusual experiences, like theatre, circus and magic. The other one is disinhibition, so people who might like to scream on a rollercoaster really let themselves go. And there's also resistance to boredom, which is a great measure to have, particularly if you're going to queue for an hour to get on a rollercoaster that lasts only two minutes.

Also, our enjoyment depends on our perceptions of risk, whether we're novelty-seeking, and, critically, how we ride rollercoasters. If I went on a ride with you, we might have a great time because we're good friends. If I go on to do a very objective scientific exploration of the ride, I'll have a different experience. If I get on it with somebody I don't like, in the rain, I could have a miserable time. There are so many contributing factors.

**YOU'VE BEEN INVOLVED IN ROLLERCOASTER DESIGN FROM THE CONCEPTION TO THE FINAL PRODUCT, RIGHT?**

Yes. I have been involved in the design of rollercoasters from early inception, for example, the Wicker Man at Alton Towers. All we knew was that they had a footprint of land and we had an audience who were demanding a new rollercoaster. After that, there were no other prescriptions for what we would make.

In a situation like that, there are several things we look at. One is what are the cultural trends in society? What novel technologies are out there? What are people talking about?

This is where the idea of a wooden rollercoaster came in. In America they're very popular but in the UK, we only have one or two. Then the theme of the Wicker Man and the horror scenario started to evolve.

> "IN EVOLUTIONARY TERMS, THRILL HAS EVOLVED AS A MECHANISM TO REWARD THE PERSISTENCE OF LIFE"

Then there are the rides like TH13TEEN at Alton Towers, where it had been pretty much finalised and I just worked on one particular feature. If you don't know TH13TEEN, you go in and – this isn't a spoiler by the way, I think most people know this before they get on – you go into the dark tunnel, the ride stops and then it falls. Your carriage falls, vertically, through the dark.

Alton Towers wanted to know, was this going to be thrilling? How far in the dark should we drop people? There's quite a precise calculation – we can work out how quickly the brain processes novel information, such as a sudden drop in the dark, and how long it takes to translate that into action, such as screaming.

That's quite a critical calculation, because if you make it too short, people aren't going to be thrilled. If you make it too long, well for every extra inch of steelwork you create, it costs tens of thousands of pounds. There's not only psychological modelling, but also economics modelling behind the whole thing.

**IN ANY OTHER SITUATION, A DROP LIKE THE ONE ON TH13TEEN WOULD FRIGHTEN ME. HOW DOES THAT TURN INTO THRILL AND EXCITEMENT?**

Yeah, I feel like my job is terrorising people! As animals, we have a really strong relationship with thrill. In evolutionary terms, thrill has evolved as a mechanism to reward the persistence of life. Now, that's evading danger – not being killed or maimed – all the way through to reproduction, sating hunger, quenching thirst, chasing prey. These are all quite exciting things. And in modern life, in our Western world, we're lucky that we rarely experience those extremes. But to feel thrilled is to feel truly alive. In a world where we don't feel thrilled, we feel flat, we don't feel excited. So, part of the appeal of theme parks and rollercoasters is replacing those mechanisms that used to naturally exist. But whereas in the wild, we truly were faced with real dangers, the job of a theme park

**ABOVE** Brendan Walker was involved with the design of the Wicker Man rollercoaster at Alton Towers, which taps into the horror genre

**ABOVE RIGHT** On rides, people experience different emotions, including joy, excitement, horror, and sometimes even boredom...

ALAMY, SCIENCE PHOTO LIBRARY

is to create the perception of danger. The actual danger of the theme park – well, you're more likely to fall off a donkey in Skegness than have any accidents on a theme park ride.

**DO YOU CONSIDER YOURSELF A THRILL-SEEKER?**

I'd always thought of myself as a real thrill-seeker. But I think my perceptions of risk are quite low.

I actually went to see if I had the 'thrill-seeking gene', as research suggests our reasons for thrill-seeking can be partly put down to genetics.

When we experience pleasure, the body releases dopamine. Dopamine binds to receptors in the body, which gives us this sense of euphoria. This is the reward feedback we get, and it can be a problem because it can lead to addictive behaviour. But in rollercoasters, think about it: we rely on this burst of dopamine.

Some people have a defect, called a polymorphism, version of a dopamine receptor gene, which means that the receptor can't bind to dopamine as efficiently. So, the body needs to produce more dopamine to give the receptors a better chance of picking it up.

I found that I have this polymorphism and I am a bona fide thrill-seeker. I'm not unusual – in the UK, around 1 in 30 people have this polymorphism. But when you go to the US and in Australia, the proportion is about 1 in 20. This is thought to be because the people who had this thrill-seeking gene were more likely to be adventurers, more likely to go and colonise these other places. But then you look at other nations such as China, where I think the occurrence is about 1 in 60. They have a different attitude to adventure, and going out and seeking new places. So, it's quite fascinating once you start charting on a global scale who has got this polymorphism.

**HURTLING AROUND A TRACK, WITH FORCES UP TO 5G, CAN BE A TERRIFYING THOUGHT...**

It sure can be. But on rollercoasters, we only experience 5g for momentary periods. The way that rides have all the banking and twists and turns, that's primarily to try to maintain the majority of the g-forces acting through the body. So – through your head, down the spine, through the seat of your pants and into the seat below you. And that's because we're pretty good at withstanding g-forces in that particular plane. If you sustain that kind of force for any period of time, blacking out is a possibility. So, they [high g-forces] usually mark transitions between different forms of motion and they can be the really thrilling moments.

**AFTER THE LOCKDOWN, WHEN I CAN GO OUT AGAIN, WHAT RIDE WOULD YOU RECOMMEND?**

For my money, I would go to the fairground and I would find a ride called the Orbit. It was one of the first fairground rides which didn't just do circles within circles, but the arms raise up and they throw you around. It's a really compact ride, and so the motions you get are really intense.

When I found out that the people who invented that ride were more used to making oil rigs and drilling equipment, it suddenly all made sense. If you imagine diamond blades at the end of these arms, whizzing around, and the whole thing boring underneath the Channel Tunnel, I think you kind of get the idea. So, when you can, go to your local fairground, find an Orbit and get on it. SF

### PROF BRENDAN WALKER

Brendan Walker originally trained and worked as an aeronautical engineer, before retraining as a designer at the Royal College of Art. He is also a technology-inspired performance artist, holding shows for audiences at the Science Museum and thrill-seekers at Alton Towers. Now, he runs Studio Go Go, where he is using virtual reality to turn 'good rides into extraordinary experiences', and Aerial, a design practice creating tailored emotional experiences. He is currently a professor of creative industries at Middlesex University.

## DISCOVER MORE

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# COLD COMFORT

by HELEN GLENNY

**Many people swear by the benefits of a cold plunge, and it seems they might be on to something. Scientists are finding evidence that regular icy dips could help relieve stress, anxiety and depression...**

Claire's* legs ache with cold as she pushes forwards into the messy grey sea, grey sand stretching behind her, grey sky above. She braces herself against each incoming wave, the wind whipping at her exposed skin. Her local beach, Scheveningen, on the western coast of the Netherlands, is a wide expanse of sand running uninterrupted beside the North Sea. It's March, and the sea temperature is about 6°C.

In the water, Claire's skin temperature drops instantly, and after a few minutes, her muscles start to cool, stiffening like chewing gum. Her swim is short, and warming up takes hours, but she's elated to be there. "We were jumping around, shrieking like schoolgirls," she says, remembering her first taste of cold water swimming. Claire needed the boost, as three months before, after suffering a personal trauma, she'd sunk into severe depression.

In the UK, where Claire is originally from, researchers are looking into the scientific benefits of cold water swimming for people who are experiencing mental health problems, such as anxiety and depression. They're dipping volunteers into troughs of frigid water in labs, and leading groups into the water beside Brighton Pier. And they're discovering that cold water immersion can prime you, mentally and physically, to better deal with any stress that might come your way.

## BODY SHOCK

One man who's leading the research into cold water swimming is Prof Mike Tipton, an environmental physiologist at the University of Portsmouth. An open water swimmer himself, he studies how people react to sudden immersion. He says that the mood benefits of cold water can be divided into two phases: the initial 'cold shock' response, and then adaptation that happens over the longer term.

If you've ever taken a wintry

*NAME HAS BEEN CHANGED ILLUSTRATION: ADAM GALE

"THIS ADAPTATION MAKES YOU LESS REACTIVE TO THE SHOCK OF COLD WATER, BUT COULD ALSO MAKE YOU LESS REACTIVE TO STRESS"

dip, you'll recognise cold shock. First, you gasp involuntarily, then hyperventilate. Adrenaline courses through your body. Your heart races. You panic. Although you can't sense it, your blood pressure is skyrocketing, and glucose and fats are being released into your bloodstream, providing an energy source should you need to make a quick escape. This is the classic 'fight-or-flight' response.

Cortisol, a stress hormone, is released from your adrenal glands, which maintains this state for minutes to hours, while a surge of beta-endorphin hormones in the brain provides pain relief and gives a sense of euphoria. This explains Claire's post-swim high, which felt so good that she and her friend made it a ritual. Every Sunday, they rode their bikes to the beach to go for a dip.

In Portsmouth, Tipton puts his volunteers through a formalised version of Claire's weekly dips to measure how they adapt to cold shock. He sits his volunteers in a hanging chair, lowers them into a trough of water at 12°C, and keeps them there for about five minutes. Tipton notes that it only takes six immersions to halve the cold shock response. In other words, your body learns to adapt: your heart and breathing rates only rise half as much, you panic less and you can control your breathing. This adaptation makes you less reactive to the shock of cold water, but it could also make you less reactive to everyday stress.

This is what researchers call 'cross-adaptation': adapt to one stressor, and you can partially adapt to others. Tipton's colleague Dr Heather Massey first demonstrated cross-adaptation in humans by habituating her volunteers to cold water, before putting them in a low-oxygen environment to simulate high altitude. The cold-adapted volunteers had a much smaller stress response to the lack of oxygen than other volunteers who hadn't been cold-adapted.

Tipton believes that this cross-adaptation could lessen your response to psychological stress, too. Although physical and psychological stress can affect the body in different ways, they also share common elements. "These stressors are always stimulating the sympathetic nervous system [the part of the nervous system that's responsible for our 'fight-or-flight' response], as well as other systems responsible for cellular tolerance to stress," says Tipton. "We think that cold water habituation resets those systems to deal with stress better."

## A SHOCK TO THE SYSTEM

While Tipton has been studying cross-adaptation in his lab, Dr Mark Harper, an anaesthetist at Brighton and Sussex University Hospitals, has been looking at the same principle at the Brighton seafront. He became interested in the potential stress benefits of cold water swimming because anaesthetised patients also go through a large physiological stress during surgery, and minimising that response could help patients to recover. While he has no current plans to test whether cold water swimming could help improve surgical outcomes, it is nonetheless an interesting hypothesis.

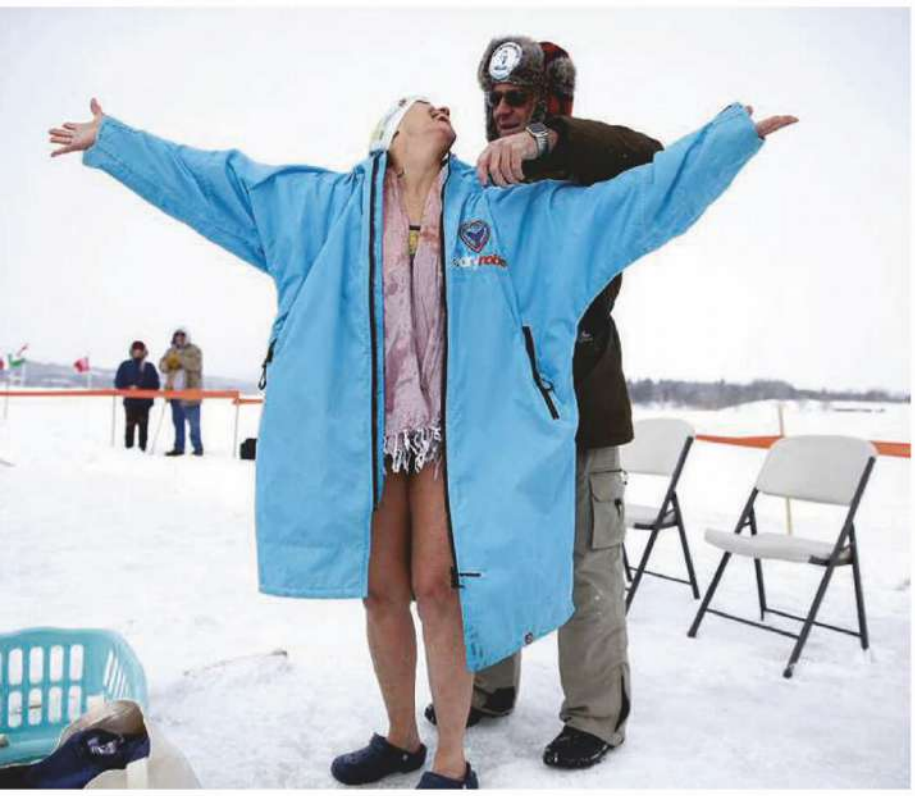
He's especially fascinated in one specific component of the stress response. Just as stress causes an adrenaline surge, preparing us to attack or to run, it also kick-starts the immune system in preparation for possible wounding or infection. This protective response, called inflammation, is healthy when stressful events are rare and isolated, but it can become chronic when people experience stress every day.

What's more, chronic inflammation has been linked to depression. One study of identical twins found that the twin with higher levels of inflammation was more likely to have developed depression when revisited five years later. And a recent meta-analysis, pooling 36 studies that covered more than 9,000 patients, found that taking anti-inflammatory medication alongside antidepressants reduced depression symptoms, when compared to taking antidepressants alone.

**ABOVE** Swimmers at Brighton Pier shun wetsuits in order to maximise the benefits of the chilly water

**RIGHT** Many cold water swimmers, like this participant at the Winter Swim Festival in Newport, Vermont, report a feeling of lasting euphoria after exiting the water

ALAMY, GETTY IMAGES



So if adapting to the stress of cold water can decrease our general stress response and reduce inflammation, it follows that it could potentially reduce our risk of depression too. However, Harper is quick to point out that depression is complex, and inflammation is likely to be one of a number of factors that play a role.

Many open water swimmers talk about how their hobby has benefitted their mental and physical health, and it's not hard to see why. The exercise itself is good for the body, and spending time by water is associated with increased wellbeing. Swimming with others fosters a sense of community, and completing a challenging task creates a sense of achievement. Harper recognises the importance of such a broad therapy: he's planning a study using cold water swimming to improve the mental wellbeing of NHS workers who have struggled through the COVID-19 pandemic.

Back in the Netherlands, Claire swum regularly over the course of a year, underwent talking therapy, and took part in mindfulness training. When she was well enough to return to work, she took up a post as the mental health curriculum leader at the school where she teaches, ensuring that the students grow up knowing how to protect their own mental health. She cites swimming as a really important part of her own recovery. When she was struggling the most, it gave her social contact and didn't require her to be at her best. "We didn't need to talk," she says, "we could just go out and shout in the sea." **SF**

## TRY IT YOURSELF, SAFELY

**If you have a history of heart disease or suffer from asthma, talk to your GP before you swim.**

**It's safest to swim with other people. There are many wild swimming groups in the UK who welcome new members – find your nearest one on The Outdoor Swimming Society's website outdoorswimmingsociety.com**

**People go cold water swimming anywhere that's deep enough for a dip: the sea, rivers, lakes, quarries, lidos. Choose a safe site, and make sure you know how to exit the water before you get in. The website wildswim.com has a crowd-sourced map of recommended swimming spots.**

**Wear a wetsuit if it makes you feel more comfortable, but the colder you feel, the better the adaptation – build up to just wearing a swimming costume. In winter, many swimmers add neoprene boots and gloves to keep their hands and feet warm, as well as a woollen hat over a silicone swimming cap.**

**Ease yourself in slowly. At first, it'll be hard to control your breathing, so it's best to get used to the cold where you can touch the bottom or hold onto a ladder. After 15 to 20 minutes in the water, you might begin to stiffen up. If you start to feel like you can't maintain a swimming stroke, get out of the water.**

**Once you're out, your body will continue to cool for about half an hour. Put on warm clothes, have a hot drink, and wait until you've warmed up before driving home.**

**For more tips on swimming in cold water, visit outdoorswimmingsociety.com**

by **HELEN GLENNY**
*Helen is a freelance science journalist with a background in neuroscience and physiology.*

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# Q&A

## YOUR QUESTIONS ANSWERED

... WHY DON'T WE GET WOKEN UP BY OUR OWN SNORING?
... WHAT'S THE SMALLEST PARTICLE?
... WOULD THE DINOSAURS HAVE EATEN US IF WE WERE ALIVE AT THE SAME TIME?
... COULD THE INTERNET BECOME CONSCIOUS?
... WHAT MAKES SOUP EXPLODE IN THE MICROWAVE?
... WHY DO I SMELL OF ONIONS AFTER I'VE BEEN WORKING OUT?
... WHAT IS THE REPRODUCTION NUMBER R?
... WHY IS A NEUTRON STAR SO HEAVY?
... WHY DO PEOPLE LAUGH WHEN THEY'RE NERVOUS?

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ILLUSTRATION: DANIEL BRIGHT

RODNEY MINNS, HAMPSHIRE

# DO ANY OTHER ANIMALS HAVE RELIGION?

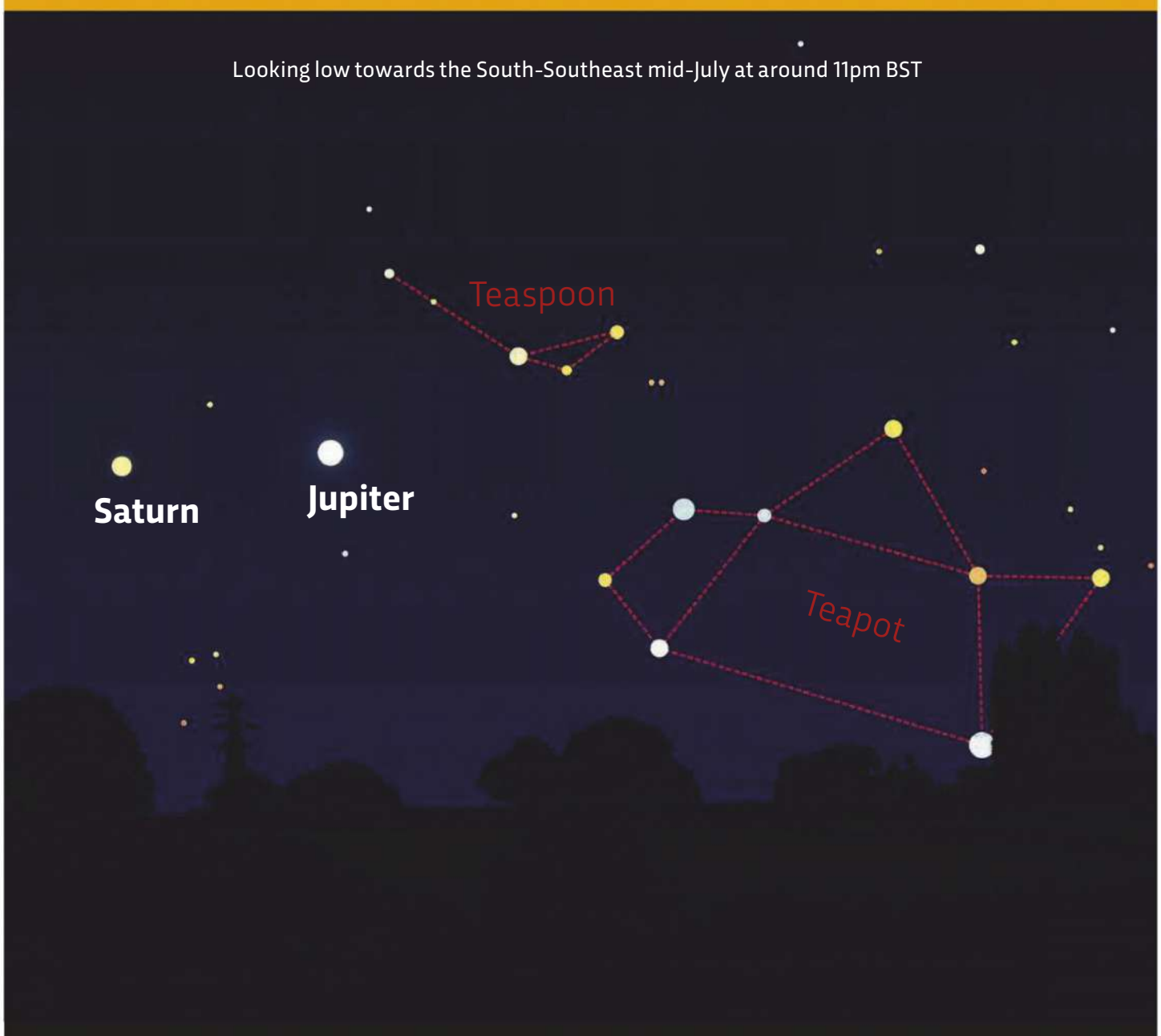
Although my dog may stare at me like I'm a deity, there's no evidence to suggest that non-human animals have religion. They don't worship, pray or believe in gods of any kind, but they do perform ritualistic behaviours, prompting some to speculate that animals could have a spiritual side.

Elephants, famously, 'mourn' their dead. Family members visit the bodies of deceased relatives, and smell and touch them. There are claims that magpies have been seen placing 'wreaths' of grass next to dead individuals. In 2018, a 'grieving' orca carried her dead calf through the icy waters of the Salish Sea for more than two weeks before finally letting it go. Putting aside the use of anthropomorphic terms such as 'mourning' and 'grief', these and other incidents still hint that some animals at least have an awareness of death and the capacity to ritualise their dead.

Rituals have been perceived in other areas, too. Jane Goodall witnessed chimpanzees dancing at waterfalls, and pondered whether the animals are experiencing feelings of awe or wonder. Other scientists have watched elephants waving branches at the waxing Moon, prompting some to wonder if the Moon holds symbolic significance for them.

It's a tough call. On the one hand, why shouldn't intelligent, socially complex animals feel awe in response to the natural world or the night sky? Maybe ritualistic behaviour does hint at a level of spirituality. On the other hand, maybe chimps just like having a boogie, and elephants just like waving sticks. Until we can read their minds, we should keep ours open. ***HP***

# ASTRONOMY FOR BEGINNERS




## HOW CAN I SEE JUPITER AND SATURN?

### WHEN: THROUGHOUT JULY

In some ways, summer stargazing is great because of the warmer nights. But the shorter nights mean that there's a much smaller window of darkness. That's why it's a great time to look for the brighter objects in the sky, like planets, which are still visible even when it's not fully dark.

This July offers the perfect opportunity to spot two of the 'naked eye' planets: Jupiter and Saturn. That's because the Earth's orbit will bring it directly between these planets and the Sun. When this happens, a planet is said to be 'in opposition'. It is the closest the planet will come to Earth – and is therefore the brightest we will see it in our night sky.

Jupiter is in opposition on 14 July, while Saturn is on 20 July.

You'll be able to see Jupiter and Saturn throughout July, close together in the sky, with both rising on the southeastern horizon. At the start of the month, you'll see them rise just after 11pm, Jupiter appearing first (it will be the brightest 'star' you can see on the horizon). By 11:30pm, Saturn will be visible to the left of Jupiter, looking a little less bright. As the days go on, the pair will rise earlier, and by mid-July, they'll be visible by 10pm. Two fun star patterns ('asterisms') to look out for close to the planets are the Teapot and the Teaspoon (see diagram).

If you have a pair of binoculars, try and spot Jupiter's four largest moons: Io, Callisto, Ganymede and Europa. How many you'll be able to see, and where you'll see them, will vary depending on the night. But on 6 July, the four moons will appear in a line, visible as two tiny 'stars' on either side of Jupiter. You can use free stargazing software such as *Stellarium* to check what you'll be able to see on a specific night. ***AB***

**17%**

**The amount by which daily global $CO_2$ emissions fell at the height of the coronavirus shutdown.**

JOEL EDWARDS, BRADFORD

## WHY DON'T WE GET WOKEN BY OUR OWN SNORING?

Your ears still receive while you sleep, but your brain filters out low-priority sounds – you're more likely to wake if you hear your own name than a random word, for example. Especially loud snores can wake up a snorer, but only partially, and they'll usually go right back to sleep almost immediately. Brainwave research suggests that even non-snorers have 20 to 25 of these 'microarousals' per hour that they don't remember in the morning. ***LV***

SARAH DEERY

# WOULD THE DINOSAURS HAVE EATEN US IF WE WERE ALIVE AT THE SAME TIME?

Let's imagine humans living 66 million years ago, alongside the biggest meat-eating dinosaur of all, *Tyrannosaurus rex*. *T. rex* surely would have been able to eat people. There are fossil bite marks, matching the teeth of *T. rex*, on the bones of *Triceratops* and duck-billed dinosaurs such as *Edmontosaurus*, which were both over 50 times heavier than an average person. But that doesn't mean we would be hunted to extinction. Like the prey of lions and tigers today, we would have been in danger, but found ways to survive. Many dinosaurs that were smaller than us survived alongside *T. rex*, and none of them had the benefit of our large brains! ***SB***

## CROWDSCIENCE

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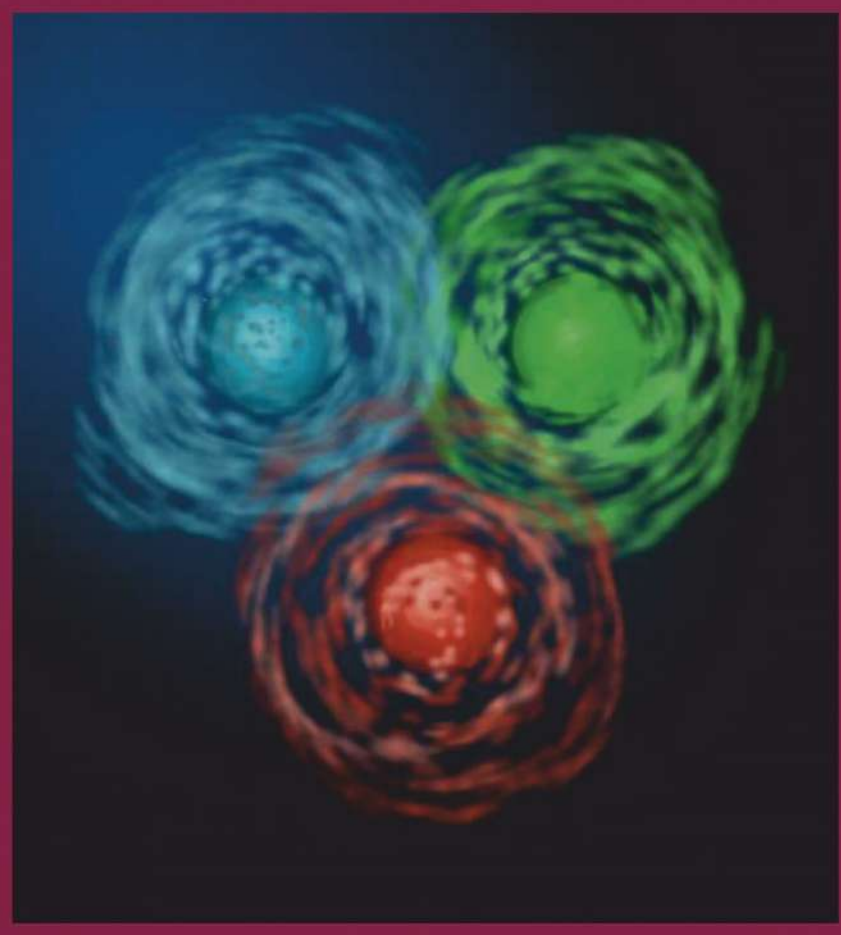
# WHAT'S THE SMALLEST PARTICLE?

The Ancient Greeks had a name for the smallest particle: the 'atom', meaning 'not cuttable'. But ever since Ernest Rutherford famously split the atom in experiments at Cambridge University around a century ago, it's been clear that the name is a misnomer. He found that atoms contain a central nucleus around 10,000 times smaller than the atom itself.

By the early 1960s, researchers firing electrons at atoms were finding hints that even the protons and neutrons making up atomic nuclei contain some kind of structure – now known to be quarks – trapped inside them. In the last few years, experiments at the Large Hadron Collider particle accelerator have suggested that quarks may themselves be at least 10,000 times smaller than protons and neutrons.

But there's one subatomic particle that's far smaller still, and not even the most powerful particle accelerator has come close to pinning down its size: the electron.

Physics textbooks sometimes mention the so-called 'classical radius of the electron', which – at around three-million-billionths of a metre – is similar to that of a proton. But this comes from a theory that assumes the electron is just a ball of electromagnetic energy, which isn't really true. A more reliable insight into its true size comes from using quantum theory, which ties the size of subatomic particles to their angular momentum ('spin') and their magnetic properties. In the case of the electron, measurements of these properties suggest that the electron is at least 1,000 times smaller even than quarks.



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NEVE SHEEHAN (AGED 9), HOVE

## WHY DO WAVES BUBBLE AND TURN WHITE WHEN THEY BREAK?

Most ocean waves are created by the wind blowing over the sea surface. The wind's frictional drag gathers up the water and turns it into waves that get taller as they travel towards the shore. As they grow, the waves become more unstable, with the force of gravity tugging at their tallest, weakest points. This causes the crests of the waves to break apart into a mass of droplets and bubbles, which scatter the surrounding light in every direction, creating the familiar white crest of a breaking wave. ***RM***

AMY THOMAS, LONDON

## WHAT MAKES SOUP EXPLODE IN THE MICROWAVE?

As the microwaves used to heat food bounce around inside the oven, they create patches of high and low intensity – and thus uneven levels of heating. The problem with soup is that it tends to be relatively gloopy (or 'viscous'), slowing the diffusion of heat within it. As a result, some parts of the soup start to form expanding bubbles of hot vapour which can burst through the surface, making a mess. Stirring the soup halfway through often solves the problem. ***RM***

## NATURE'S WEIRDEST CREATURES...

# THE GREAT POTOO

**No, it's not a cartoon character, and no, we didn't run it through a Snapchat filter. This tropical oddity, with enormous ping pong ball peepers and a ridiculously oversized mouth, is one of our planet's most bizarre birds: the great potoo.**

**Standing up to 60cm tall and with a wingspan of over 70cm, the great potoo is the largest member of the Caprimulgiformes – an order of birds that includes the nightjars and frogmouths. Nocturnal by nature, the great potoo has eyes that take up much of its skull, giving it excellent night vision, while unusual slits in the eyelids help it to sense the movement of approaching predators even while asleep.**

**Native to South and Central America, the great potoo is a world leader at pretending to be a tree stump, spending most of its time perched upright on branches. During the day, its mottled feathers help it to hide from predators in plain sight. During the night, the bird has an excellent vantage point from which to pluck insects, such as beetles and moths, out of the air. The great potoo is also a talented vocalist – its moaning growl sounds like an angry fox gargling a Jägerbomb. Happily, its call is likely to endure for years to come, as this avian oddball isn't listed as a threatened species. *HP***

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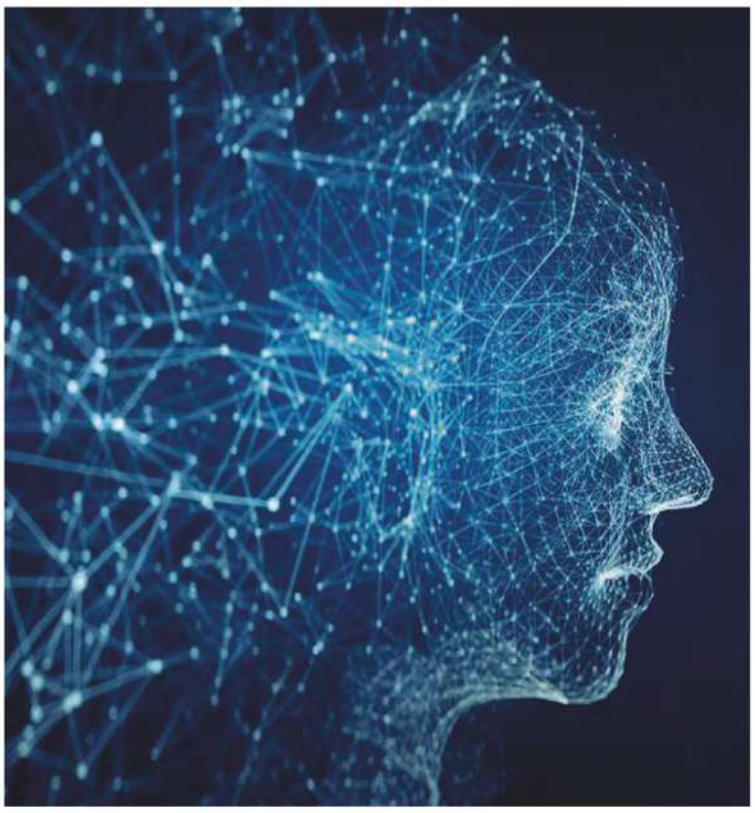
EDWARD SEYMOUR, HOVE

# COULD THE INTERNET BECOME CONSCIOUS?



An old belief system called 'panpsychism' suggests that something resembling a mind or consciousness exists in all physical things. In recent years, researchers such as neuroscientist Christof Koch have tried to update these ideas, saying that if there are enough connections between elements – like synapses in the brain – then consciousness may naturally start to form. The average human brain has 86 billion neurons, with some 100 trillion connections between them – does this mean that if something else has the same number of connections, it will also become conscious? Some believe so.

Like our brains, the internet is a massively connected entity, made up of computers, mobile devices and the 'Internet of Things' (IoT) – smart, networked objects including household appliances, wearable gadgets, vehicles and even entire factories. According to one estimate, the number of internet-connected devices will reach 125 billion worldwide by 2030. So the connectivity of the internet seems to be fast approaching that of our brain.

But how would we know if the internet had become conscious? An internet that's as connected as the brain might process information as quickly as we do, but that doesn't mean it's going to 'wake up' or become self-aware. There are big differences between the two systems: our sense of consciousness is created by brains that have evolved over millions of years, whereas the internet is a human-designed network that's been around for a few decades. Ultimately, consciousness is still such a poorly understood subject that we won't have a definitive answer to your question until we figure out how to measure consciousness in the first place. ***PB***

# DEAR DOCTOR...

## DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

## WHY DO I SMELL OF ONIONS AFTER I'VE BEEN WORKING OUT?

**You have two kinds of sweat glands in your skin. 'Apocrine' glands exist only on certain parts of your body, such as your armpits and groin area, and produce an oily fluid in response to emotional experiences such as anxiety, pain and arousal. 'Eccrine' sweat glands are much more numerous and distributed all over the body, and they're responsible for your workout sweat.**

**The purpose of eccrine sweat is to cool down the body as it evaporates from the skin. Eccrine sweat is more than 99 per cent water and completely odourless – at least when it first leaves your pores. But the bacteria on your skin feed on the scant nutrients in the sweat, along with any loose skin flakes. One of the by-products of their metabolism is a group of sulphur-containing chemicals called thioalcohols. The exact thioalcohols produced will depend on your unique menagerie of skin bacteria, but some thioalcohols do indeed smell strongly of onion. Their whiff is overpowering because our noses are capable of detecting thioalcohols at concentrations of as little as one part in a trillion. The protein responsible for this part of the bacterial metabolism was identified at the University of York in 2018, giving hope for deodorants that prevent bacteria from producing thioalcohols. Until then, a shower is still the best remedy. *LV***

## WHAT CONNECTS...

### PANDAS AND AGATHA CHRISTIE?

**1.**
Giant pandas have a diet that almost exclusively consists of bamboo shoots and leaves. A single panda must eat up to 40kg of bamboo per day because of its low nutritional value.

**2.**
Bamboo releases dangerous levels of hydrogen cyanide when eaten raw. In 2016, Chinese researchers identified an enzyme that pandas use to convert the cyanide into a less toxic compound called thiocyanate, which they excrete in their urine.

**3.**
Cyanide is poisonous because it blocks the function of an enzyme called 'cytochrome c oxidase'. This in turn stops the mitochondria present in all living cells from using oxygen to produce energy. As a result, heart muscle and nerve cells run out of energy and die within minutes.

**4.**
Crime writer Agatha Christie originally worked as a pharmacy dispenser and was fascinated by poisons. Cyanide was her favourite, and accounts for 18 of her fictional murders in 10 novels and four short stories.

ALEX BRAMWELL, CARDIFF

## WHAT IS THE REPRODUCTION NUMBER R?

The reproduction number – often called the R value – is a measure of a disease's ability to spread. It tells us how many people a single infected person will pass a disease to.

The R value for COVID-19 that's being quoted in the media and government briefings is what's known as the 'effective' reproduction number. This value can go up and down. We can reduce R by making it harder for the disease to spread, by implementing measures such as social distancing, closing restaurants and non-essential shops, and encouraging people to stay at home.

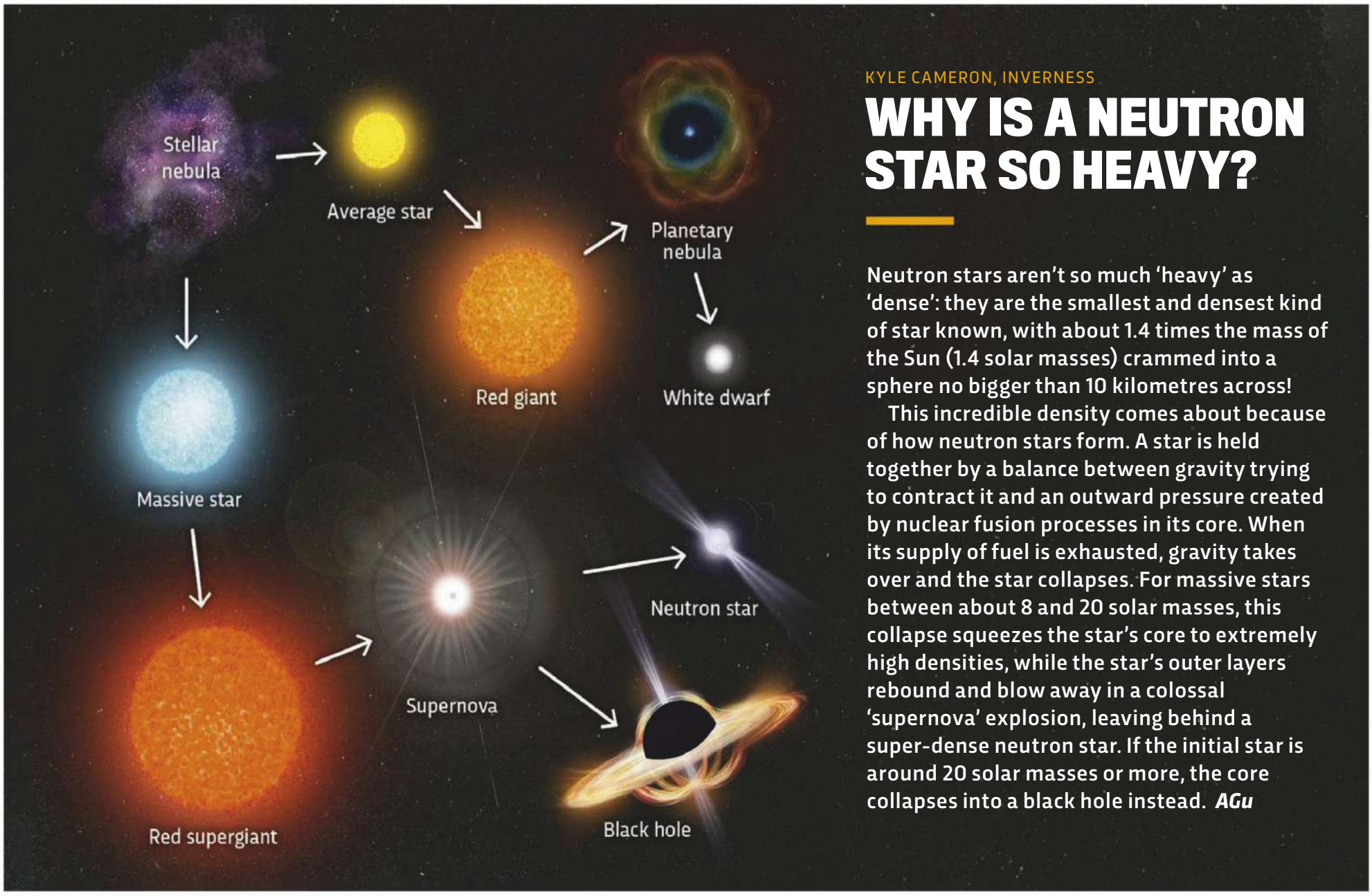
Every disease also has what's called a 'basic' reproduction number, R0, which is the fixed value of R if no measures are put in place. For example, measles is highly contagious, with an R0 as high as 18, while COVID-19 has a R0 of around 3. Therefore, if COVID-19 was allowed to spread through the population, an infected person would, on average, give the disease to three other people. But if these people are practising physical distancing, the virus can't spread so easily and the effective R value goes down.

The crucial thing is to keep R below 1. If we can do this, then the number of new cases will dwindle and the outbreak will eventually come to a halt. Conversely, if R rises above 1, then we run the risk of rapidly escalating case numbers that would require stronger measures to keep the virus under control. Because of this, R is used by governments to assess how we are doing in our efforts to stop the spread of COVID-19, and to adjust our actions, if needed. ***JR***

ISMAIL FULAT

## WHY CAN'T WE PREDICT PRIME NUMBERS?

Prime numbers, which can only be divided by themselves and 1, are the building blocks of all whole numbers, yet no comprehensive formula for them has ever been found. The most famous is $N^2 + N + 41$, which generates primes for every value of N from 0 to 39 – which isn't very impressive, given there's an infinite number of primes. Such failure has led to an assumption that primes must be randomly distributed. But in 2016, a team of mathematicians at Stanford University found that primes ending in 1 were less likely to be followed by another ending in 1 than would be expected from a random sequence – hinting at some sort of hidden pattern. ***RM***




KYLE CAMERON, INVERNESS

## WHY IS A NEUTRON STAR SO HEAVY?

Neutron stars aren't so much 'heavy' as 'dense': they are the smallest and densest kind of star known, with about 1.4 times the mass of the Sun (1.4 solar masses) crammed into a sphere no bigger than 10 kilometres across!

This incredible density comes about because of how neutron stars form. A star is held together by a balance between gravity trying to contract it and an outward pressure created by nuclear fusion processes in its core. When its supply of fuel is exhausted, gravity takes over and the star collapses. For massive stars between about 8 and 20 solar masses, this collapse squeezes the star's core to extremely high densities, while the star's outer layers rebound and blow away in a colossal 'supernova' explosion, leaving behind a super-dense neutron star. If the initial star is around 20 solar masses or more, the core collapses into a black hole instead. ***AGu***

## QUESTION OF THE MONTH

YASMIN HAYES, LONDON

## WHY DO PEOPLE LAUGH WHEN THEY'RE NERVOUS?

The most obvious function of emotional displays like laughter and crying is to signal to others what we're feeling. But the fact that we laugh when we're nervous shows this isn't the whole story. Sometimes our emotional displays can be a way to mask our true emotions. If we've done something embarrassing, for example, we might laugh to cover up our feelings of shame or shyness. Nervous laughter could also be a way to help us regulate our emotions. We usually feel more relaxed after we laugh, so a nervous chuckle when we're feeling socially anxious can help to alleviate some of those negative emotions. ***CJ***

### WINNER

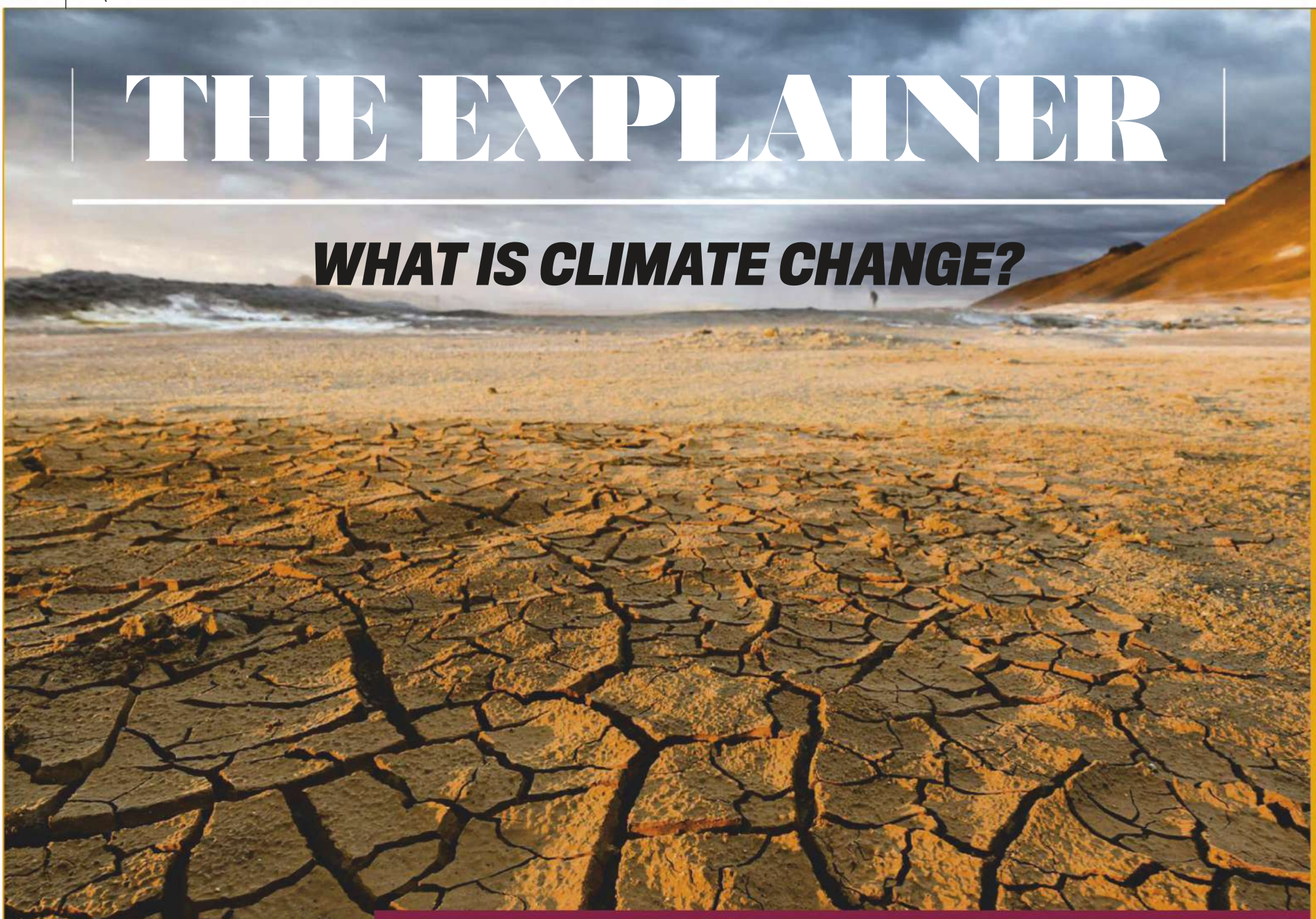
Yasmin wins a Trust GXT 788RW 4-in-1 Gaming Bundle, worth £59.99. It includes a keyboard with rainbow illumination, a gaming headset with 40mm speaker units, a futuristic-looking mouse with six buttons, and a mousemat. **trust.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

GETTY IMAGES X6, ALAMY ILLUSTRATION: DANIEL BRIGHT

# THE EXPLAINER

## WHAT IS CLIMATE CHANGE?



### IS CLIMATE CHANGE THE SAME AS GLOBAL WARMING?

People often use the terms 'climate change' and 'global warming' to describe the same phenomenon: an increase in average global temperatures, caused by humans adding heat-trapping greenhouse gases into our planet's atmosphere. But while some places are getting warmer as a result, other parts of the globe might sometimes be cooler. And ocean or atmospheric temperatures aren't the only thing changing: weather patterns and sea levels are too. Some people therefore prefer to use the term 'climate change' as it covers the full range of predicted impacts. 'Climate crisis' is another term you might hear.

### WHAT'S THE EVIDENCE FOR CLIMATE CHANGE?

Temperature records show that our planet's average surface temperature has risen by about 1°C since 1850. Most of this warming has taken place in the past 35 years, and the five warmest years on record have all occurred since 2015.

There's a growing body of evidence for rising temperatures and their effects. As ocean water warms, it expands, causing global sea levels to inch higher. A 2018 study showed that sea levels had risen by an average of seven centimetres over the previous 25 years. Around 40 per cent of this was due to thermal expansion, with the rest due to melting ice sheets in Antarctica and Greenland, and melting glaciers. The Greenland ice sheet, for example, lost an average of 280 billion tonnes of ice per year between 2002 and 2016.

Extreme weather events are also on the rise. It's difficult to trace any one event back to climate change, but places around the world are seeing a marked increase in the frequency and severity of droughts, floods, wildfires and tropical cyclones.

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## ARE HUMANS TO BLAME?

The overwhelming scientific consensus is that humans are responsible for climate change. In fact, one 2019 analysis of over 11,500 peer-reviewed articles on the topic found a consensus of 100 per cent. By burning coal, petrol and gas to heat our homes, power our cars and generate electricity, we have released huge amounts of carbon dioxide and other greenhouse gases into the atmosphere. These in turn trap heat in our planet's atmosphere, amplifying the greenhouse effect.

The greenhouse effect itself occurs naturally, and gas levels and global temperatures do change over time, but the current rates of change are alarming scientists. In its Fifth Assessment Report, the UN's Intergovernmental Panel on Climate Change (IPCC) wrote that concentrations of the greenhouse gases carbon dioxide, methane and nitrous oxide are "unprecedented in at least the last 800,000 years", and many of the corresponding changes in our climate system are "unprecedented over decades to millennia".

## HOW BAD WILL IT GET?

Left unchecked, climate change will have devastating consequences for our planet and its inhabitants. If emissions continue to rise, the IPCC estimates that we could be on track for 3˚C of warming over the 21st Century, possibly even 4˚C in a worst-case scenario. Many scientists consider 2˚C or even 1.5˚C to be the target to aim for if we're going to avoid the worst consequences.

As our atmosphere and oceans continue to warm, the increased amount of heat will feed more tropical storms and cyclones. Sea levels will continue to rise, possibly by as much as one metre, making some coastal regions uninhabitable. And there will be changes in rainfall patterns: some areas will experience more flooding; others more drought. Plant and animal species will be driven to extinction as their habitats shrink or their food supply dwindles, while increased carbon dioxide levels will make the oceans more acidic, harming marine life.

The pace of warming is expected to pick up over time because of self-reinforcing mechanisms known as climate feedbacks. For example, melting permafrost in the Arctic and Siberia releases methane that has been locked away for millennia, fuelling even more warming.

## WHAT CAN WE DO ABOUT IT?

Tackling climate change will require cooperation on a global scale, bringing together governments, businesses and individuals. We'll need to wean ourselves off fossil fuels and onto renewable energy sources and sustainable transport options. We'll also need to change the way we consume, by making more sustainable choices or simply buying less.

New technologies, be it super-efficient solar panels or electric cars, will play a vital role in reducing emissions. But they are not a silver bullet, and proposed methods to remove carbon dioxide from the atmosphere have not yet been tested on a large scale.

Nonetheless, our efforts are beginning to pay off. Greenhouse gas emissions are slowing in some parts of the world: the UK's emissions, for example, have fallen by 29 per cent over the past decade. And national leaders the world over have pledged to work together to limit global temperature increases, signing the Paris Agreement in 2016.

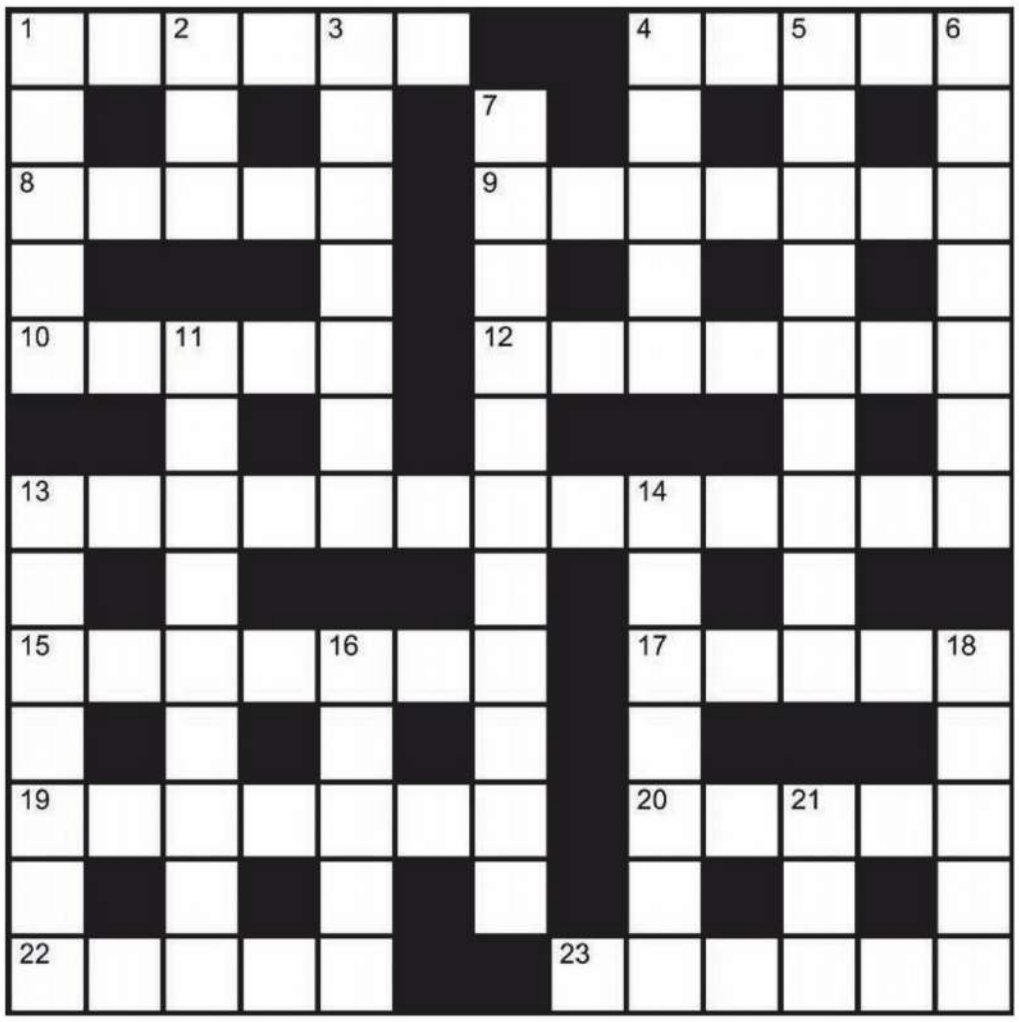
But experts agree that the change is not happening fast enough. To ensure the future of our planet, we're going to need to ramp up our efforts.

by ALEX FRANKLIN CHEUNG

*Alex is a science writer with a degree in environmental science.*

# CROSSWORD

## GIVE YOUR BRAIN A WORKOUT



### ACROSS

**1** Model transposed unknown tune (6)
**4** Clean energy, following city (5)
**8** Finish initial game with defeat (5)
**9** Free publication (7)
**10** Article thanks foreign character (5)
**12** Your first listener follows novel celebration (3,4)
**13** Graduate, legally a non-union member (8,2,3)
**15** Giant goal – hit construction (7)
**17** Unexpectedly greet a bird (5)
**19** Bent around everything in sport (7)
**20** Exhausted from some wrestling (3-2)
**22** Terribly eager to concur (5)
**23** Doctor backing a new firm in principality (6)

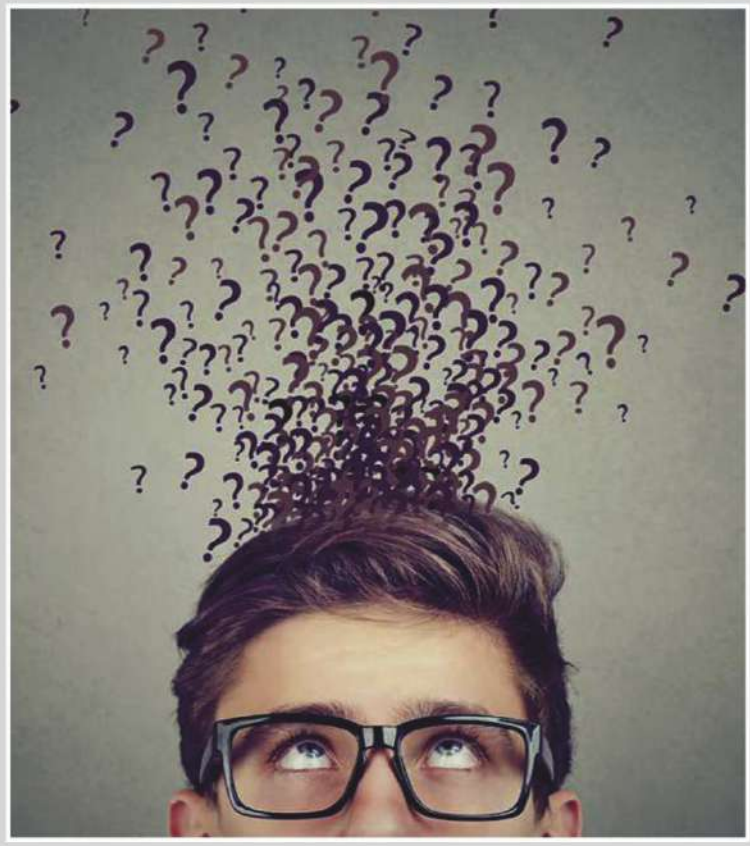
### DOWN

**1** Strength in May (5)
**2** Sign from galleon (3)
**3** Daughter is to relax complaint (7)
**4** Feel depressed underneath (5)
**5** Cashier rings artist with five for tourist (9)
**6** Feature has an intellectual sound (7)
**7** French lover is half porcine, sadly (11)
**11** Stairs somehow scale a hill (9)
**13** Transported a being with old flower (7)
**14** Alternatively, gone mad about a herb (7)
**16** Quickly find a quiet expert (5)
**18** Got an alternative routine (5)
**21** Permissible, angling around field (3)

**ANSWERS** For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

## ALL YOU KNOW ABOUT PSYCHOLOGY IS WRONG



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## MARS MATTERS

We talk to a planetary scientist hoping to find organic minerals on Mars.

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We go behind at the scenes at RAF Marham, where they assemble the F-35 – the first jump jet stealth fighter that you fly without looking out of the windows.

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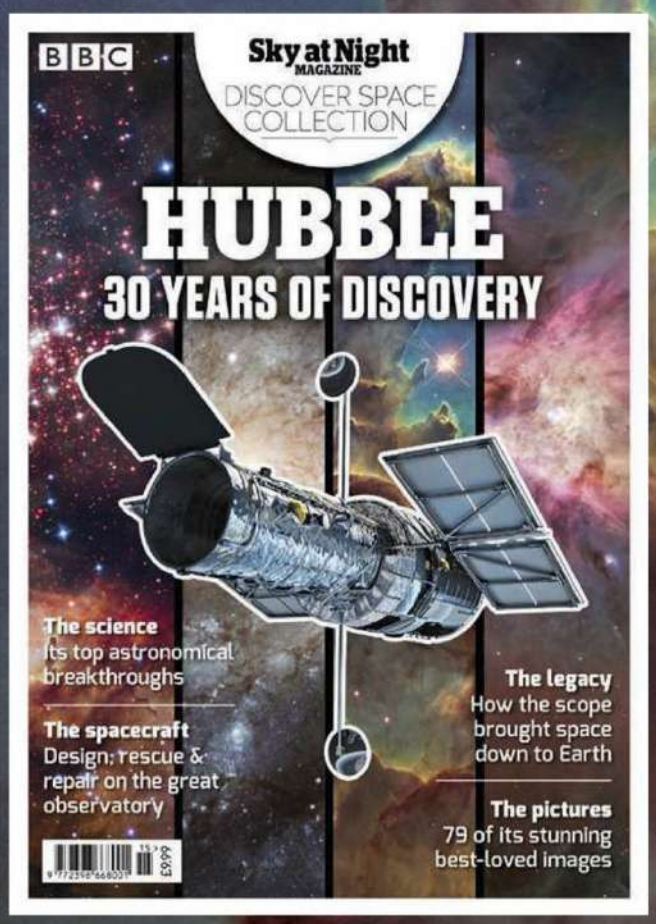


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A SCIENTIST'S GUIDE TO LIFE

# HOW TO LOOK AFTER YOUR SKIN

CONSULTANT DERMATOLOGIST **DR BAV SHERGILL** REVEALS HOW TO KEEP YOUR LARGEST ORGAN LOOKING PEACHY

**LESS IS MORE.**
Most people don't need anything more than a basic cleanser and moisturiser, and sunblock if you're going outside.

**SOME SKIN NEEDS MORE HELP.**
There are about 3,000 skin-related conditions, such as eczema and psoriasis. If your skin is scaly, dry and red, then you may be advised to follow a particular routine. In this case, moisturisers can help to rehydrate the skin, and short bursts of steroids can ease inflammation.

**MOISTURISERS DON'T 'GIVE' WATER TO THE SKIN.**
This is a common misconception. Moisturisers provide a protective barrier and work by allowing the body to transfer water from deep down in the skin to the top layers.

**EXPENSIVE CREAMS AREN'T NECESSARILY BETTER.**
There's some interesting psychology going on here. Sometimes, we pay extra for the branding, the packaging and the ethos, and we value things more because they're expensive. If you have specific needs, it might be worth paying a bit more. Products that contain vitamin B3, for example, are excellent for people with brown patches of skin known as 'melasma'.

**ANTI-AGEING CREAMS CAN MAKE A DIFFERENCE.**
Peer-reviewed studies show that vitamin A-based chemicals, such as retinol and retinoic acid, can improve the appearance of fine lines. They boost the production of collagen and can help to even out skin tone by banishing blemishes. Be careful, as strong doses can cause irritation.

**THERE'S NO DIFFERENCE BETWEEN MALE AND FEMALE SKINCARE PRODUCTS...**
... Apart from the packaging and the scent. That said, I like the blue colour of my products, so I've clearly been seduced by the branding!

**YOU DON'T NEED SEPARATE DAY AND NIGHT CREAMS.**
Although if you're applying a cream that contains retinol, it may be better to apply it at night, as retinol can make the skin slightly more sensitive to sunlight.

**AVOID DRINKING LOTS OF ALCOHOL.**
If your body is dehydrated, your skin will be too. Keep hydrated and eat a healthy diet. Foods or supplements that contain vitamin C and E are good because they're antioxidants that prevent damage from free radicals.

**THINK ABOUT WHAT YOU WEAR.**
Wear a broad-brimmed hat between 11am and 3pm during sunny months. This is a good idea, especially for men who are losing their thatch on top. You see a lot of people who have sun damage because their hair is thinning and they thought they were still protected on top. SF

DR BAV SHERGILL
*Bav is a consultant dermatologist who specialises in the treatment of skin cancer. He is a member of the British Association of Dermatologists.*
***Interviewed by Dr Helen Pilcher***

## NEED TO KNOW...

**1**
A basic cleanser and moisturiser (and sunblock) is all that most people require.

**2**
Expensive isn't necessarily better, but look for key ingredients if you have certain needs.

**3**
Eat healthily and don't drink too much alcohol if you want your skin to look its best.

ILLUSTRATION: JOE WALDRON

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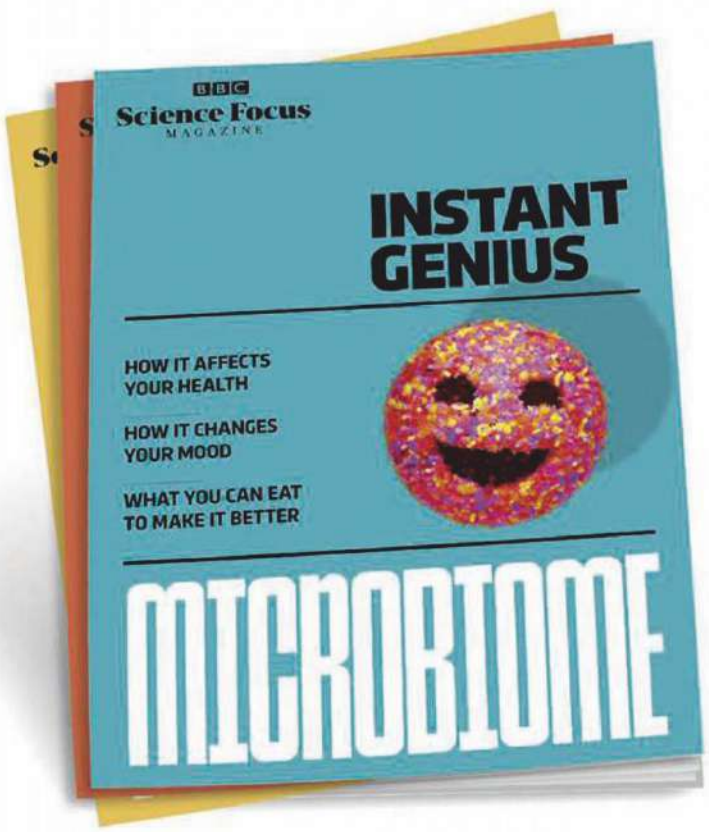


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